THE NATURE-STUDY OF PLANTS

T. A. DYMES

THE HERB ROBERT, GERANIUM ROBERTIANUM, LINN.

Reduced to $\frac{3}{8}$ actual size.

THE NATURE-STUDY OF PLANTS

IN THEORY AND PRACTICE FOR THE HOBBY-BOTANIST

BY

THOMAS ALFRED DYMES, F.L.S.

WITH AN INTRODUCTION BY

PROF. F. E. WEISS, F.R.S.

WITH FRONTISPIECE AND 53 ILLUSTRATIONS (21 PHOTOGRAPHS)

Whatsoever thy hand findeth to do, do it with thy might.—
ECCLES. ix. 10.

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1920

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DEDICATED

TO

THE STAFF AND PUPILS

OF

THE UXBRIDGE COUNTY SCHOOL

IN

GRATEFUL APPRECIATION

OF

THE EDUCATION THAT MY DAUGHTERS

RECEIVED THERE.

INTRODUCTION

FOR the study of Nature it is essential to go to Nature herself, and no one, least of all the writer of this little book, who is essentially a close observer of Nature, would wish to advocate the teaching of natural science by books alone. On the other hand, the stimulus of a well-presented account, gathering up the knowledge gained from careful observation and experiment is undoubted, and in this respect most of the present work has been tested by the author and an appreciative audience of eager and inquiring young minds. The first part interprets to the young student of Botany the meaning of the many phenomena of plant life which he or she may have been studying, and represents an attempt at outlining a mental picture of the closely interdependent functions and of the adaptations observed among plants, by explaining the factors of vegetable life, whenever it is possible to do so, in terms familiarly used of human life. Those who have not had opportunities of detailed study of plant life will no doubt find in these pages an incentive to make a personal investigation of the fascinating processes which make for the preservation of the individual and of the race. The second part, dealing with the Life-History of the Herb Robert and its relatives, will, I hope, convince both teachers and scholars how much may be learnt from a careful study of a single member of our common British plants. Such an intensive study of the growth to maturity of a plant involves a realization of all the factors which mould the various organs. This method of minutely following the life of a plant through all its varying stages has been adopted with considerable success in at least one school with which I am acquainted. I warmly recommend the particular example described in this work to the attention of teachers and to all who desire to become acquainted with the many-sided activities of one of our common, but, at the same time, one of the most attractive of Flowering Plants.

F. E. WEISS.

THE UNIVERSITY,
MANCHESTER,
November 27, 1918.

PREFACE

THERE is nothing to be said by way of Preface to this book except so far as the illustrations and the help that I have received from my friends are concerned.

I have to thank Miss Emily Dust, of Manchester, for the Frontispiece, which she was kind enough to sketch from a living plant. Turning to the photographs, Messrs. Newton & Co., of Covent Garden, supplied me with that of the fruits and seeds of the Yellow Flag, and Mr. W. Tams, of Cambridge, with those of the seed of the Ragged Robin and of the Cut-leaved Cranesbill. The shoot and the spent fruit of the latter and all the other photographs are the work of Messrs. Flatters & Garnett, Ltd., of Manchester.

With four exceptions the material from which the plates and illustrations were taken was supplied by myself .I am indebted to the Rev. Henry L. Graham, of Eastbourne, for plants of the shingle variety of the Herb Robert; the Cluster-cups on the leaf of the Barberry were supplied by Messrs. Flatters & Garnett, Ltd.; while the sketch of the single one of the Stinging Nettle is the only botanical illustration not taken direct from the thing itself. I did not get to this point until August, which was too late in the season for this species, and I did not think it worth while to postpone matters for another year on that account. The last exception is the sketch of the beetle Coeliodes, which was taken from a Museum specimen.

There remains the very pleasant duty of offering my cordial thanks to those of my friends who have been good enough to assist me, especially to Prof. F. E. Weiss, F.R.S., and Mr. W. C. Worsdell, F.L.S. Both of them have given me very valuable advice and help, and while Prof. Weiss has kindly contributed an introduction, Mr. Worsdell has generously relieved me of most of the tedious but nĕcessary task of making the Index; moreover, it was almost entirely at his suggestion that I decided to deal in these pages with the relatives of the Herb Robert.

Dr. D. H. Scott, F.R.S., has also allowed me the benefit of his advice whenever I sought it and Mr. H. St. J. K. Donisthorpe, F.E.S., has helped me with the entomology.

Again I derive great encouragement from the interest shown in my book by friends who are neither botanists nor naturalists: assistance of this nature is invaluable, with a charm and a virtue all its own.

Finally, my readers will, I am sure, agree with me that our thanks are due likewise to the photographers for their excellent work.

T. A. DYMES.

"Carthona," West Drayton,
Middlesex,
October, 1919.

TO THE READER

THE sign × with a number after it indicates the magnification: thus, for Fig. 1, Plate I., p. 10, ×**70** means that the photograph is seventy times as long and seventy times as broad as the piece of leaf-skin itself. It would therefore take four thousand nine hundred such pieces, or seventy rows of seventy each, to cover the photograph without leaving any spaces between them.

If, however, we turn to the illustration of the seed of the Ragged Robin Fig. 26, Plate II., p. 70, and arrange thirty rows of thirty seeds apiece, we shall more than cover the photograph. We shall have a figure which is not the same shape as the seed, but a rectangle which will overlap the photograph at the angles, because there will be spaces between the seeds, and the total area of these spaces will exactly equal the total area of the overlap. In other words, if we draw four straight lines at right angles to one another around the photographed seed so as just to touch it on each side, we shall find that the nine hundred seeds will just cover the rectangle.

The reader will be well advised to look at the illustrations, and especially the photographs, through a low-power reading glass.

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FROM

THE REV. C. A. JOHNS' "FLOWERS OF THE FIELD."

30th Edition, 1902.

REVISED BY G. S. BOULGER, F.L.S.

POPULAR NAME.	SCIENTIFIC NAME.
Aconite	Aconitum Napellus
Anemone, Wood	Anemone nemorosa
Ash	Fraxinus excelsior
Avens, Yellow	Geum urbanum
Barberry, Common	Berberis vulgaris
Beech	Fagus sylvatica
Belladonna	Atropa Belladonna
Bellflower	Campanula (all British species)
Bindweed	Volvulus sepium
Birch	Betula verrucosa
Bird's Eye	Veronica Chamædrys
Bluebell	Scilla festalis
Borage	Borago officinalis
Box	Buxus sempervirens
Bramble	Rubus fruticosus
Brooklime	Veronica Beccabunga
Bryony, Black	Tamus communis
Bryony, White	Bryonia dioica
Bugloss, Viper's	Echium vulgare
Buttercup	Ranunculus acris
Celandine, Lesser	,, Ficaria
Charlock	Brassica Sinapistrum
Chickweed	Stellaria media
Cleavers	Galium Aparine
Clover, White	Trifolium repens
Columbine	Aquilegia vulgaris
Convolvulus, Corn	Convolvulus arvensis

POPULAR NAME.	SCIENTIFIC NAME.
Cranesbill, Bloody	Geranium sanguineum
,, ,, Pink variety ...	,, ,, *var.* lancastriense
,, Cut-leaved	,, dissectum
,, Dusky	,, phæum
,, Long-stalked ...	,, columbinum
,, Meadow	,, pratense
,, Mountain	,, pyrenaicum
,, Round-leaved ...	,, rotundifolium
,, Shining	,, lucidum
,, Wood	,, sylvaticum
Cress	Lepidium sativum
Cuckoo-flower	Cardamine pratensis
Cuckoo-pint	Arum maculatum
Cudweed	Gnaphalium uliginosum
Daffodil	Narcissus Pseudo-narcissus
Daisy	Bellis perennis
Dandelion	Taraxacum officinale
Deadnettle, White	Lamium album
Dock...	Rumex obtusifolius
Dovesfoot	Geranium molle
,, Small	,, pusillum
Elm	Ulmus campestris
Enchanter's-nightshade ...	Circæa lutetiana
Flag, Yellow	Iris Pseudacorus
Flowering-rush	Butomus umbellatus
Foxglove	Digitalis purpurea
Goatsbeard	Tragopogon pratense
Gorse	Ulex europæus
Grass, Rye	Lolium perenne
Groundsel, Common	Senecio vulgaris
Hawthorn	Cratægus Oxyacantha
Hazel	Corylus Avellana
Hemlock	Conium maculatum
Henbane	Hyoscyamus niger
Herb Robert	Geranium Robertianum
,, Shingle variety ...	,, ,, *var.* purpureum
Heronsbill	Erodium (all British species)
Hop	Humulus Lupulus
Houseleek	Sempervivum tectorum
Lettuce, Wild	Lactuca virosa
Lily, Turk's Cap	Lilium Martagon
Lords and Ladies	Arum maculatum
Maple	Acer campestre
Marsh-marigold	Caltha palustris
Monkshood	Aconitum Napellus
Mullein, Great Yellow	Verbascum Thapsus
Mustard	Brassica alba
Nettle	Urtica dioica and U. urens
Oak	Quercus Robur
Orchis, Bee	Ophrys apifera
Pine	Pinus sylvestris
Pink	Dianthus plumarius

POPULAR NAME.	SCIENTIFIC NAME.
Plantain	Plantago major
" Hoary	" media
Poppy	Papaver (all British species)
" Yellow-horned — ...	Glaucium flavum
Primrose	Primula acaulis
Ragged Robin	Lychnis Floscuculi
Rattle, Yellow	Rhinanthus Crista-galli
Rose, Briar	Rosa rubiginosa
Scabious, Small	Scabiosa Columbaria
Sedge, Wood	Carex sylvatica
Self-heal	Prunella vulgaris
Shepherd's-purse	Bursa pastoris
Silverweed	Potentilla Anserina
Sloe	Prunus spinosa
Snapdragon	Antirrhinum (both British species)
Snowdrop	Galanthus nivalis
Speedwell	Veronica polita
Spurge, Petty	Euphorbia Peplus
" Sun	" Helioscopia
Stitchwort	Stellaria Holostea
Stock	Matthiola incana
Stonecrop	Sedum acre
Storksbill	Erodium cicutarium
Sycamore	Acer Pseudo-platanus
Thistle	Carduus (all British species) and Cnicus (all British species)
Toadflax, Ivy-leaved	Linaria Cymbalaria
" Yellow	" vulgaris
Violet, Sweet	Viola odorata
" Wood	" silvestris
Wallflower	Cheiranthus Cheiri
Willow Herb	Epilobium montanum
Wood-sage	Teucrium Scorodonia
Wood-sorrel	Oxalis Acetosella

THE NATURE-STUDY OF PLANTS

PART I. THEORY

CHAPTER I

NATURE-STUDY—ITS OBJECT AND RULES

BEFORE launching out into the deep it behoves me to explain shortly what is meant by Nature-study, and to bring to the notice of the reader a few points and rules which will, I trust, be of some use in the intelligent pursuit of his hobby or study.

Although the term itself is a comparatively modern one, Nature-study is no new thing; on the contrary, it is the most ancient and essential of all the activities of the human mind, for in one or another of its aspects, man has persistently and of necessity studied Nature from the time of Adam to the present day.

Its central idea is crystallized in the motto of one of our leading learned societies, *Naturae discere mores*, which means, "To learn the ways of Nature," and this is the object that the modern Nature-student should keep steadily before his eyes.

He must, however, never be content only to learn facts, however interesting they may be; he must try to find out their significance in the life-history of his subject and their bearing upon the greater problems, presented sooner or later to all those who take up the study of Nature for their recreation or their life-work. He cannot learn her ways unless he be acquainted, not only with facts, but also with their meaning in relation to others, with which the connection is often a great deal more real than apparent.

We do not, however, when speaking of Nature-study, use the term in its widest and universal sense, but we confine its meaning more especially to the study of the living animals and plants of the world, to the animate as opposed to the inanimate creation: although it should not be forgotten that the latter is a part of Nature which must by no means be neglected, for it is not possible to understand fully the life of any organism, whether animal or vegetable, without knowing a little about the physical conditions under which it lives and to which it must make an adequate response or else die.

Nature-study, therefore, is capable of demanding a great deal from those of its devotees who are ambitious, and very much more than can be expected reasonably from any one who turns to it merely as a recreation and a hobby.

It is for the hobby-rider that I write with a view to pointing the way to small beginnings which can be extended, if so desired, almost indefinitely, but I do not aim at exhausting even the comparatively small number of points with which I deal.

There are many more ways than one in which Nature can be studied. Students confined themselves, in my early days, almost exclusively to collecting specimens, giving them names, and then putting them away in a cabinet, without perhaps ever looking at them or referring to them again. Now I have not one word to say against collecting, naming, and classifying. Those were some of the things that had to be done before Nature-study as we know it to-day could be undertaken at all, and we may well be proud of and grateful to the great Englishmen and Frenchmen whose labours over many generations have contributed so largely to our present-day knowledge ; it is because they did their work of description and classification so well that we are able to launch out and explore realms unknown to them. That work is still far from completion, and, moreover, it demands the very best in the way of intellect and mental vision.

Its results, as enshrined in our Floras, for example, are of incalculable value to the Nature-student, whose work cannot be carried on unless he too does a certain amount of collecting and is careful about naming his plants correctly. His programme must, however, include a very great deal more than that, for he should try to add something to our knowledge of the natural history of the members of our Flora and incidentally of our Fauna too. To put it as shortly as possible, he should aim at finding out, as far as he can, what his particular plant does, why it does it, and how, and I propose offering a few hints gleaned from my own experience as a hobby-botanist.

It is often, but not always, easy to see what a plant does, it is sometimes not difficult to understand why it does it, but it is frequently very hard to discover how it does it.

If we bury a bulb of a daffodil in the soil we shall see that it grows into a beautiful plant which produces a flower and seeds. It is not difficult to discover reasons why it should do this, but I think nobody need be ashamed of owning to a great deal of ignorance when it comes to the question of exactly how it manages it, and it is just those things which are not known that the Nature-student should try to find out.

The wish to know must not only be present, but it must be the driving force; curiosity and enthusiasm are a *sine quâ non*, since, without them, nothing in this world is ever done as well as it might be. The interest in the work must be irresistible, and the concentrated absorption while it is being done must be complete.

Patience is an essential, and so is a mental build that can not only seize the fleeting opportunity, but is also capable of waiting, content, by virtue of an imperturbable faith, with slow progress and without any misgivings as to the ultimate result.

Accuracy in making and recording observations must also be cultivated assiduously. It has been said, with profound wisdom, that it is very easy to see what we go out to look for, which means that if we are hoping or expecting our subject to do this, that, or the other, there is a danger of misinterpretation in favour of preconceived ideas. Again, it is just as easy to overlook what we are not expecting or prepared for, and it is sometimes very annoying to find that we have missed a chance, either from carelessness or inexperience, which cannot be retrieved for another twelve months.

Such things are bound to happen, but they should not discourage us. Experience will soon reduce the human liability to error and in the course of time convert the tyro into an expert.

Thoroughness and method in keeping the records are invaluable, and in this connection there is a rule that I should like to insist upon now, because its neglect discounts the value of many an observation or even renders it worthless until it is repeated and perhaps corrected too.

The student should carry with him a note-book in which he should write down his observation on the spot and at once, instead of five minutes or half an hour later on, or the next day ; furthermore he should always record the time and the exact date in full—day, month, and year—as well as the name of the parish and the kind of place, such as a wood, a meadow or a garden, damp or dry, sunny or shady : faithful observance of this rule is a great deal more profitable than the beginner is likely to realize.

Curiosity, enthusiasm, patience, faith, accuracy, thoroughness, and method, all these are as necessary for Nature-study as they are for other things, and as sure of their reward in the fullness of time. They are the muscles and strength of the student, while his tools, so to speak, are observation, experiment, and quiet thought, for he must reason and ponder in order to be able to interpret his observations and experiments aright.

Nature-study does not, of course, interest everybody : its appeal, happily, is not universal nor should we allow it to become exclusive. Most sensible people, including naturalists, find interest and treasure in more subjects than one, some of which are more immediately useful and remunerative ; nevertheless, quite apart from practical utility, actual and potential, Nature-study is of very great value in the training and education of character.

I propose, by way of helping the reader to know what to observe and what experiments to make, to bring before his notice what we mean when we talk about the life of a plant, but before I do so I must draw his attention to three more golden rules which must be observed ceaselessly alike in Nature-study and in all other scientific research work.

The first is always to see and do things for himself whenever it is by any means possible. It is not always easy, although, in the long run, it is seldom impossible, to keep this rule. If he is really interested in the subject he will not mind awaiting the opportunity, it may be until next year, or the year after, or even longer, and he will find that being on the alert is the very surest way of seeing a chance and the most powerful incentive to take it; Keenness is the joyful and prolific mother of splendid children.

The second, equally invaluable, is to stick to one thing at a time and resolutely to leave the side issues, however attractive they may be, until that one thing is done. Never neglect what has been taken in hand for the sake of something else.

The third rule, quite as important as the other two, and certainly not the easiest to keep whole and undefiled, is never to undertake more than one can reasonably hope to do thoroughly, or, in other words, not to have too many irons in the fire. It is far better to do one thing well than two or three indifferently, and of much greater value to Science and its devotees.

These few rules cannot be emphasized too strongly or respected too scrupulously. I shall, however, have to refer again to the first of them in the last chapter.

In what follows I wish it to be understood that I claim no special merit and no superiority for my own methods, but I may perhaps say that I at any rate have found them serviceable; nor have I any doubt that, if they do not suffice for ensuring an increase in the number of competent Nature-students, they will, at least, help to attain that very desirable end.

My plan, in a few words, is to think of and study the life of a plant, as far as possible, in terms of our own life, and in trying thus to discover the answers to the questions which observation suggests the student will begin to realize, not only what a wonderful thing a plant is, not only the mighty part played by the vegetable world in the Scheme of Creation, but also what a beautiful world is the one in which we live here and now. It will be borne in upon him that what we call Nature, the animate and the inanimate creation, plants and animals, earth and air, winds and rain, rivers and mountains, heat and cold, light and darkness, labour and rest, all work together to carry out and perfect that scheme: that Nature is not merely war and strife, living and dying, self-seeking and materialism, but, on the contrary, an all-embracing co-operative society, and that her children one and all contribute to the common good.

We cannot always see the part played by this one or that, but if we have steady eyes, a brave heart, and a well-balanced mind, we shall be convinced, beyond all possibility of doubt, that things always have worked, and always must work, together for good, good in the past, better to-day, and, in the future, perfection, that

> "One far-off divine event
> To which the whole creation moves."

CHAPTER II

THE FACTORS OF LIFE—THE LIFE AND PRESERVATION OF THE INDIVIDUAL—RESPIRATION, NUTRITION, AND GROWTH

IT may be said, I believe, without exaggeration that only a few of the many persons who love flowers have ever grasped the fact that a plant is alive, that it really lives in the sense of breathing, being nourished, growing up, and having its children; but we must realize all this and a great deal more if we want to have an accurate and a reasonably complete mental picture of the life of a wild plant.

If we look, for example, at a grass, a dahlia, or an oak tree, and then at ourselves, we may very naturally, but withal erroneously, think that it is absurd to suggest that life, even in its essentials, means very much the same for all living things.

I am, however, quite sure that we shall commence studying Nature's wildlings to very much better effect if we realize once and for all the universal truth of that fact.

Let us think of our own life, what we mean by the word stripped of all that is unessential, and then let us compare it, factor by factor, with the life of a plant.

I. Respiration

Every one of us, irrespective of age, knows quite well that in order to remain alive, even for a very few minutes, we must keep on breathing, and that is true of the plants as well. If we deprive them altogether of oxygen they die inevitably: they must breathe ceaselessly in order to remain alive. Respiration is indeed a very difficult subject, nevertheless it is common knowledge that we take air into our bodies through two holes, which we call our nostrils. We must not go into the question of what happens to it or what it does when it gets into our lungs, but we must be content with the simple and well-known fact that air enters our body for breathing purposes through holes; our own are large enough to be seen quite easily, and, except for the fact that some people make the mistake of breathing through their mouth as well, they are confined to our two nostrils. But what about the plant? It will perhaps be somewhat of a surprise to learn that it, too, admits air into its body through holes. They are too small to be seen without the aid of a microscope; we can, however, locate them quite easily with the help of a lens, which every lover of Nature, whether student or not, should possess, carry about with him, and use frequently.

We shall also require a little cold water, a glass rod, a glass "slip," and a "cover." The last three can be obtained from any optician at a trifling cost.

We shall want the rod for transferring some water drop by drop on to the slip. Slips are pieces of thin glass used as slides for the microscope, a very convenient size being three inches by one. The cover is the small piece of very much thinner glass that is placed over the object on the slip. Covers can be had either circular or square, and the former are the more useful, especially when wanted for a circular drop of water or other liquid.

We shall have to choose a plant from those whose leaves are smooth and without hairs, and we shall find none better than a snowdrop, a tulip, a hyacinth, a narcissus, or a lettuce.

We must have a small pair of sharp scissors handy, and we must take a slip and put upon it a large drop of water.

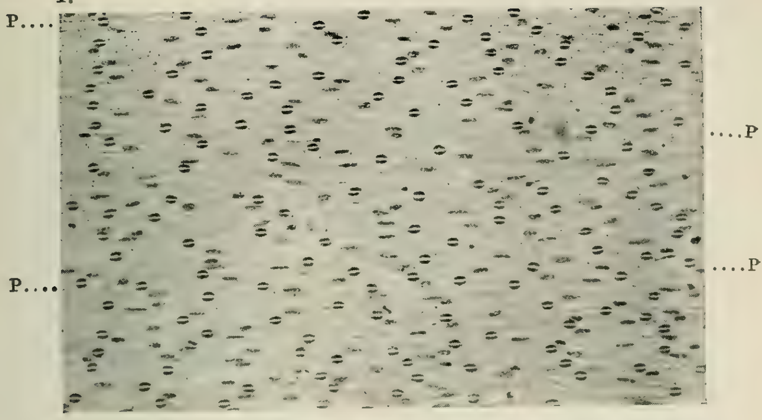
The next thing is to take the leaf and break or cut it across, but not into two : we must not break the skin of the lower surface. We shall then be able, quite easily, to strip a piece of the colourless skin from the underside.

The thinnest part of the strip will be the end farthest from the breakage. With a little practice and the help of a little more water and the pair of scissors we shall soon be able to manœuvre a small transparent bit into the water on the slip ; we must then put another drop of water on to it and place a cover over the thinnest part. If we now hold the slip to the light and look at the strip through a lens we shall be able to see, not the holes themselves, but the places where they are and where they will be found, if we are fortunate enough to possess a microscope or a friend who will give us the necessary help with his own.

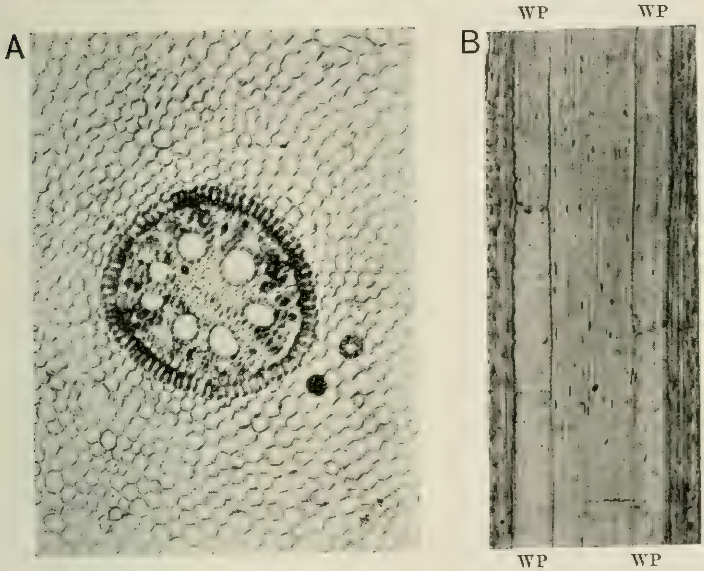
With a lens, however, we can see quite plainly that the bit of skin has darker dots upon it. In the centre of each dot there is a single hole : it is not a round hole, but about twice as long as broad, and in the snowdrop it is so small that its length is hardly $\frac{1}{1000}$

PLATE I.

I.



II.



I. Skin from the underside of a leaf of the Snowdrop to show the pores. × 70. P = pore, between two short lines: the, usually longer, single lines are not pores. Fig. 1.

II. The Root of the Yellow Flag. A, cut across; B, cut lengthways. In A the pipes appear as a ring of seven holes in the central darker circular area; in B two conspicuous pipes are marked WP. × 70. Fig. 3.

of an inch. These holes are sometimes, but quite wrongly, called little mouths, and we had better understand clearly that their proper name is "pore." It is through them that the air gets inside the plant's body. I should be afraid to say how many there are on a single leaf of the snowdrop, but it is quite certain that we could not possibly count them one by one on the two leaves which the bulb produces annually unless we devoted an eight-hours' day to it for days together at the rate of a hundred per minute.

We see, then, that as regards the first Factor of Life there is a very pronounced agreement between plants and ourselves. In order to remain alive we both admit air into our body, for breathing purposes, through holes ; in ourselves we call them our nostrils, and in the plant "pores."

Breathing was the first thing done, after birth, by all the people and all the animals and all the plants that have ever lived in this world, and all of us go on doing it throughout the whole of life.

Now, breathing is one of the things that use up the body, and I need hardly remind the reader that a dwindling body is not exactly one's idea of physical fitness. In childhood it has to be built up until it is full grown, and then it must be kept the proper size ; but, on the other hand, it is always being worn away in the process of respiration. Whether we are enjoying a good sound restful sleep or taking a brisk walk, we wake up or we come home hungry, and this is Nature's danger signal. It means that our life-substance must be built up again if we are to retain our health and vigour, and the way to do this is, of course, to take food.

II. Nutrition

The subject of vegetable nutrition is one of surpassing interest, but in this book it cannot be explained in detail or allowed more than an illustration or two.

I may remind the reader that our own food, or, more accurately, the nutriment which it contains, consists of what are known as carbohydrates and proteids. The former, among which are sugar and starch, are built up of carbon, hydrogen, and oxygen, the last two elements being in the same proportion as in water—that is to say, there is twice as much hydrogen as oxygen. The proteids are very much more complex; the water relation between the hydrogen and oxygen that they contain is not respected, and in addition to carbon we find nitrogen, sulphur, and other elements necessary to adequate nutrition, such as phosphorus.

Carbohydrates and proteids, as we might expect from their different composition, do not serve the same purpose in the economy of the human or animal body; the former are used up in respiration for keeping us warm and supplying us with energy, while the latter go to replace the wear and tear of life and its activities. It is by them that our life-substance is nourished and our bones, muscles, and brains formed and kept in good working order. Now, as a matter of fact, plant food consists, like our own, of carbohydrates and proteids, and they are utilized for the nutrition of the plant body in a similar way.

How plants manage to get the food is a question of which I can only touch the fringe; but there is this great difference between them and us—we eat ready-made food and then digest it, but plants do not eat in the sense of chewing and swallowing their food, on the contrary, each green plant makes its own food in its own body and subsequently digests the products of its own work. I purposely said that each green plant makes its own food, because there are a few flowering plants in our own country, and many more elsewhere, that are not green, and they feed in a different way ; but the student will learn about them and the insectivorous plants as his Nature-study progresses, and we must not allow them to lead us away from the main point now.

To return to the ordinary green plant, its food is formed inside its body by the co-operation of its root and leaves, the atmosphere and the sunlight. The root absorbs some of the ingredients dissolved in the soil water, and the leaves admit others from the atmosphere through the same pores that act as breathing holes.

The water taken up by the roots is conveyed to the leaves through pipes which run throughout the length of the plant, and it is inside the leaves that the two sets of ingredients meet and are forged into food with the help of sunlight.

We can see some of the actors in this process with the help of a lens and a little perseverance. If we dig up a plant and look at its roots we probably shall not see the organs that absorb the water, for they are so fine and delicate that they are almost certain to be broken off and left behind, and even if they are not they will probably be hidden by small particles of soil.

We can observe them best by taking a seed of mustard or cress, for example, and letting it germinate upon a saucerful of wet sand or a piece of damp flannel, it will soon push out a rootlet which, as can be seen quite easily with a lens, is covered almost, but not quite, to the tip with a fine felt of comparatively long threads, known as root-hairs, and it is they that absorb the soil water.

FIG. 2.—Germinating seed of Mustard a fortnight after sowing on damp sand, to show the root-hairs between A and B. × 2.

It is also fairly easy to locate the water-pipes, at any rate in some plants, although we shall not see them very plainly until after a good deal of practice. It does not very much matter what root we take so long as it is large enough to be handled and sliced without difficulty; let us try one of the thickest roots of the Yellow or the Blue Flag. We must cut it off near the thick top and put about an inch or so of the thickest part of it into a small bottle of methylated spirit and leave it there for three or four days or longer in order to harden it; then with a sharp knife or razor we must take the thinnest slice we can manage off the thickest end and put it into a drop or two of spirit, already placed upon a slip, and cover it as we did when preparing the skin of the snowdrop's leaf for examination.

The next thing is to hold the slip to the light and look at the section, as such a thin slice for the microscope is called, through a lens. We shall see small holes through the middle of it.

Now, the pipes run up the root, so we shall have cut a ring off them, and, as it were, be looking into them. We now know the part of the root where they are to be found and that will help us to see them lengthways. In order to do this we must slit the root in half down the middle, and then take a section off the slit surface and put it on to the slip in a drop or two of spirit and cover it as before. If we have had good luck we shall then be able to make out the meaning of the illustration. (See Fig. 3, Plate I., p. 10.)

We can proceed in the same way with the stem and the leaves and so trace the pipes right into the latter; they are to be found in the veins of the leaves, and, of course, the thickest veins are the easiest to deal with. We must pass over what happens to the food ingredients inside the leaves, except to say that a leaf is not green in the same way that a dress or a piece of blotting paper is green—that is to say, it is not green through and through. We may have noticed, when we stripped the piece of skin off the snowdrop's leaf, that it was not green, at any rate so far as we could judge, and if we cut the leaf across or lengthways we shall perhaps be surprised by the comparatively little evidence of green that we can find in the bulk of it.

The fact is that the green consists, not of any continuous layer or layers, but is distributed as small specks in the life-substance. It is really a liquid which saturates the specks, and it is in these green "corpuscles" as they are called that the food ingredients are forged by the sunlight into food.

One of the commonest forms that the food takes, and the one that is the easiest to see, is starch, and most people are aware of the fact that starch enters very largely into our own food, such as potatoes and rice; so we find that vegetable flesh derives nourishment from the selfsame foodstuff as our own flesh, and we have another vital point of agreement in the lives of plants and ourselves.

I want the student, as I have said, to see things for himself, and there is no difficulty about the ocular demonstration of starch grains in the plant body.

He should take, and place upon a white china saucer, a small slice, about an eighth of an inch thick, of a raw potato or the thick, root-like stem of the Blue Flag that creeps along or just below the surface of the soil in our gardens: it is better for this purpose than the Yellow Flag because of the whiteness of its flesh. Sufficient pressure must be applied to squeeze out some of the moisture and then a little weak solution of iodine in water must be added. The result will be that the slice will change colour and turn a light or a darker blue according to the strength of the solution. Clusters of grains of the same colour will be found in the surrounding liquid; but all starch grains are tiny little things, and the student will have to use a microscope should he determine to make out their form for himself, for the solution will enable him to see them only in clusters, but not individually even with a lens; they are usually more or less round or oval, so I illustrate those of the Petty Spurge, which are of a very different shape.

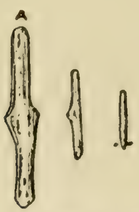


FIG. 4.—Starch grains of Petty Spurge.

A, the longest one observed, measured $\frac{1}{500}$ of an inch. × 800.

There is a very remarkable fact that I must not omit about starch grains. We constantly see advertisements of "manufacturers" of starch, but the real truth is that nobody in the world knows exactly how it is produced. Instead of being manufactured by men, all the starch we buy is made by plants from which men extract it. If there were no plants there would be no starch, and it may surprise us to learn that there would be no food of any kind whatever; we should all starve. That is one of the astounding facts of Nature that I cannot go into now, but I want the reader to believe it and think about it, for it will help him to reverence the Scheme of Creation and its Creator, and reverence is one of the virtues that is as valuable to the Nature-student as it is to all the rest of the world, whatever the occupation or hobby may be. We must never forget that if there were no green leaves there would be no animals, no men or women, and no children; moreover, should the student pursue this subject he will find that we depend upon the plants not only for the food we eat, but also for the air we breathe; he will learn that we use up the oxygen and eat up the food, but the plants replenish the supplies of oxygen, which is as necessary for them as for us, while they are manufacturing the food that sustains both. If we really grasp that fact in the sense of understanding how it comes about, we shall never have any doubt about the true meaning of the Balance of Nature or about the reality of those things which our Nature-study will reveal to us, such as the extreme beauty of the world in which we live, the co-operative nature of the Scheme of Creation, and a thousand and one other things which will compel our reverence and make life on this planet, however humble it may be, a privilege and a glory.

Now we have got two Factors of Life, Breath and Food, or Respiration and Nutrition, and if we watch a young plant, a young animal, or a child in healthy surroundings we shall very soon be aware of the third, which is Growth.

III. Growth

All healthy young things grow, and it is easy enough to understand that they grow because when they are born the body is not fully developed, some of its organs are not yet fully formed, and it has, as we say, to grow up.

I said in the first chapter that it is often very hard to discover how things are done ; but if we want to get some little idea of how we grow we can hardly do better than consider the lilies of the field, for we both of us do so in the same way.

Let us look once more at a section of a root or a stem. If we examine it with a lens we shall see that it is divided into innumerable little compartments, each of which, with its contents, is called a cell. Now, it is common knowledge that in course of time the green spring shoot of a tree becomes first a brown twig and ultimately a thick branch or bough, and one would like to know exactly how all this is managed. Confining ourselves to the increase in size, it will perhaps occur to us that it might be brought about in more ways than one ; the cells, for example, might go on growing larger indefinitely, or they might become more numerous after attaining a certain size, and if we compare a section from a young thin stem with another from an older and thicker one we shall find that the latter is the method adopted.

Growth, then, is effected by an increase of the cells, not in size but in number.

That does not tell us much, it does not explain in the least how they increase in number; it is, however, something to have satisfied ourselves that they do so. To understand even a little of how it is done would demand a good deal of work, but, to put it as concisely as possible, each young cell increases in size until it is full-grown and then it divides into two by forming in its interior a new partition, and this sort of thing goes on over and over again in different parts of the plant's body until it too is full-grown. That is how a plant grows, and that also is how we grow.

Our body, like that of the plant, is built up of cells, and growth is brought about in each case by the repeated division of existing cells resulting in an increase not in their size but in their number.

Now we must think of these three Factors of Life, Respiration, Nutrition, and Growth, as being very closely connected with one another. Respiration, the true function of which is to keep us warm and to supply us with energy to work and play, wears away the life-substance of our body, and nutrition repairs the waste by building it up again. They are the two truly vital functions upon which all life depends; but the third factor, growth, is not a vital function in the same sense, it is a result: it is the result of adequate nutrition. In healthy young children, animals, and plants nutrition adds more than respiration uses up, and so the body increases in size. In adults, on the other hand, respiration and nutrition are pretty evenly balanced, and so we keep the same size. If we are not properly nourished our body wastes visibly, and if we are gross and greedy in our feeding we are apt to become fat, coarse, and bad-tempered because we have taken more food than our body can use, and that is a very nasty and wrong thing to have done.

We find, then, that as regards the first three factors, the two vital functions and their result, there is nothing to choose between plants, animals, and human beings; all live under precisely the same laws, enjoying health and vigour when they respect them duly, but suffering distress, weakness, or death when from one cause or another the normal relations between respiration and nutrition are interfered with or brought altogether to a standstill.

CHAPTER III

THE FACTORS OF LIFE—THE LIFE AND PRESERVATION OF THE INDIVIDUAL—PROTECTION AND REST

IN the last chapter I pointed out that Respiration and Nutrition are the two vital functions, and that together with Growth they constitute the three factors upon which life depends primarily; but they are by no means the whole of life, even for a plant, to say nothing of ourselves.

Let us think for a moment of other things that we do or want in order to go on living. We must, for example, have a home or at least shelter of some sort and clothes to wear; but why is it that we must have clothes? One reason in a civilized country is, of course, that we wear them for the sake of decency, even when we imagine perhaps that we should like to take them off and sit in our bones during the heat of a summer day.

But we must remember our tender skins, and that without any covering at all we should suffer from sunscorch and burns, as indeed we do on our hands and face. So it appears that we wear clothes not only for the sake of decency but also as a protection; they protect us from heat and sunscorch, as well as from cold and wet, and Protection is the fourth Factor of Life.

IV. Protection

This is a very great subject, so great that one could write many a long chapter about it, and I must therefore divide it up into sections and leave the student to enlarge them for himself as he pursues and progresses in his Nature-study.

I need not go into the measures of protection adopted by ourselves against the many and varied ills to which human beings are exposed, but both for us and the plants the latter fall quite naturally under three main heads, namely, the elements, living things of other kinds, and mutual competition.

(*a*) *The Elements*

Against these our chief protection is in our homes and our clothes, and as far as clothes are concerned we can find something of the same sort in the vegetable world too.

As a matter of fact we are not in this country particularly well off for plants with conspicuously woolly leaves or stems, but we have at any rate the Cudweed which likes a damp soil, the Great Yellow Mullein of our dry waste places and the silky Silverweed which is to be found upon our roadsides as well as in other much moister localities.

Each of these gives us an instance of protection by long hairs which in the Cudweed and the Mullein are matted into such a close felt that we cannot see the surface of the leaf at all.

Hairs of this sort have, as we shall see later on, other uses too, but at the moment we are concerned with protection from the elements, and they protect the leaves not only from cold and damp at night, but

FIG. 5.—Hair of the leaf of the Great Yellow Mullein. × 50.

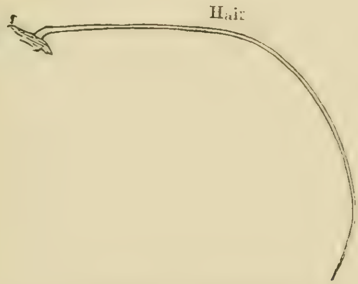


FIG. 6.—Hair of the leaf of the Silverweed. × 10.

also from being scorched and dried up in the hot sunshine, and drought is one of the greatest difficulties with which plants have to contend, for loss of water soon spells loss of life. Among many other such protective structures there are the bark of our trees and the waxy bloom that we find upon such fruits as sloes and such leaves as those of our garden carnations and pinks. Bark is composed of dead cells which form a thick protective covering over the delicate living cells within, and if we bear in mind how absolutely essential it is for plants to avoid being dried up we shall soon discover many other delightful protective contrivances.

In drawing attention, however, to the paramount importance of an adequate supply of water, I must caution the reader that there is such a thing as water in the wrong place. The right places, so far as our land plants are concerned, are inside the cells or in the soil where it can be absorbed by the root-hairs; the wrong places are, amongst others, on the skin of the leaves or inside the flowers.

If the pores were to become choked with water it would soon compromise both respiration and nutrition, hence hairy or waxy leaves serve a double purpose so far as water is concerned; for while helping to conserve the internal supply they are a protection against it in the wrong place externally; neither the rain nor the dew can reach the skin and choke the pores of a hairy leaf, and water runs off the waxy ones as readily as off a duck's back.

There is also another happening of similar significance that I must not omit to mention because it is often, but quite erroneously, spoken of as Sleep, and I may as well say at once that there is no such thing in the vegetable world. We shall come to the question of Rest later on ; but when we talk about going to sleep we imply losing consciousness, and we can hardly talk about plants doing that.

What is known as the sleep of plants, the closing up, for example, of the leaves of the White Clover, and the flowers of the Daisy at night, is really a device which affords protection from cold and dew. If we keep our eyes open we shall soon find a great many instances of this sort of thing in a great many different kinds of plants, and when we come across them we must think of them, not as sleep, but as a protection against chill and damp.

(*b*) *Living things of other kinds*

There is a good deal to be said on this subject. In our own country civilization has abolished the danger of attack from wild animals at any rate, though we still suffer sometimes from small insects and from such fearful scourges as the tiny organisms which we call germs and which produce diphtheria, small-pox, consumption, and other terrible evils. Our chief protection against them is a healthy, clean, wholesome life and the advance of medical science. We look to our religion and doctors to show us how to live so as to avoid disease and to cure it when we are unfortunately victimized.

Now, one of the chief dangers to which plants are exposed is that of being eaten alive; we must remember that they supply the food for the whole of the animal world, so it comes about that they must be adequately protected, not from ever being eaten at all, but from being exterminated or reduced too greatly in numbers, for if that were to happen animal life as well as our own would very soon be in jeopardy and on the high road to extinction.

There are, therefore, as we might expect, many different ways in which plants are protected against being eaten off the face of the earth: they stand, as it were, for ever on the defensive, and it is most important to remember that their weapons are of this nature and not those of offence.

With the exception of the few that are insectivorous they do not attack, but they defend themselves with sufficient success against being attacked. In this connection the bark, of course, is of great value. Although it supports a certain amount of small life that may open a door to disease-germs, it offers no temptation to most animals and it makes it hard for them to reach the succulent cells within. A few caterpillars have, however, got the better of it, and those of the Goat Moth, with their powerful jaws and detestable smell, bore right through it and devour the living tissues and other parts within.

Internal feeders of one sort or another are sufficiently numerous and well known to naturalists, but nevertheless bark, whether the thick covering of a tree trunk or the thin one of a shrub or bush, prevents a very great deal more disaster than the comparatively small amount against which it is powerless.

The hairs which I have already mentioned are useful for warding off the attacks of grubs and caterpillars and such horrible things as greenfly and the germs or spores of some of the worst diseases from which plants suffer, such as rust, smut and mildew. There are too, other kinds of hairs to be found in the vegetable world, which are not dry and dead like those of the Mullein and the Silverweed, but quite the reverse.

If we look through a lens at the leaf of a Briar Rose we shall see that it possesses a number of hairs each of which has a round knob at the end, known as a

FIG. 7.—Glandular hair of the leaf of the Briar Rose. × 15.

FIG. 8.—Glandular hair of the leaf of the Groundsel. × 60.

G = the gland.

gland because it produces a special secretion, while those of the Common Groundsel are like a string of beads, the head or terminal cell being the gland. Such glandular hairs occur upon a great number of plants, and whatever additional uses they may have there is no doubt that they often save their possessors from being eaten.

But there are other and much more obvious defensive weapons to be found, such as the prickles of the Rose, the rough harsh hairs of the Borage and Viper's Bugloss, the spines of the Hawthorn and the Gorse, and the stings of the Nettle.

These are a few of such weapons of defence which have only to be looked for in order to be found by any one who cares to take the trouble. The brown bulbous base of the hairs upon the Viper's Bugloss can be seen quite plainly with the naked eye, and if one handles the plant carelessly one's smarting hands keep one aware of the fact for at least an hour or two afterwards.

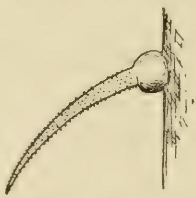


FIG. 9.—Hair of Viper's Bugloss. × 25.

The Nettle's sting, however, must be examined with a lens if we want to get a good view of the swollen base that contains the acrid poison, and there are many other plants the defensive weapons of which are not so easy to observe.

The leaves of many Grasses and Sedges, for example, have edges which are distinctly rough to the touch, but they are really very much worse than that, for they are fine and sufficiently sharp saws. A little magnification will show the teeth. This feature of the Sedges, which characterizes the stem as well as the leaves of some of them, is sufficiently pronounced to have given them a scientific name, Carex, which is derived from a Greek word meaning "to cut." I have not infrequently had my own fingers cut quite deeply enough when collecting specimens, and in addition to keeping slugs, snails, and caterpillars at bay such saws as these are capable of inflicting nasty wounds on the soft and tender lips and tongues of browsing animals.

(a) 

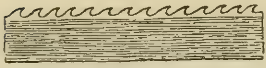
(b) 

FIG. 10.—(*a*) Margin of leaf, Rye Grass. × 35. (*b*) Margin of leaf, Wood Sedge. × 35.

Most Grasses are particularly hard and difficult to chew, the reason being that they are clad in a flinty mail in the shape of a coating of silica, the substance which forms the bulk of an ordinary flint; while straw is hard, shining, and decidedly uninviting as food, for there is a good deal of silica in it as well. The teeth, too, which form the fine fret-saws on the edges of the leaf, are minute but hard, sharp flints, to which fact they owe their efficiency.

Mineral secretions of one sort or another commonly act as a defensive weapon in the vegetable world, but some practice is required to discover them.

A very common and rather pretty plant in many parts of the country is the Enchanter's-nightshade, and its leaves are protected from small marauders in a most interesting way. Many of the cells contain very small bundles of needle-like crystals each of which has the advantage, so far as the plant is concerned, of a sharp point at each end.

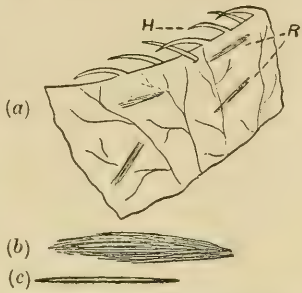


FIG. 11.—Needle crystals (Raphides) of the leaf of the Enchanter's-nightshade. (*a*) R = Raphides. H, Hair on margin of leaf. × 25. (*b*) Single bundle of raphides. × 100. (*c*) Single crystal. × 100.

Although the longest of them are hardly more than about $\frac{1}{100}$ of an inch in length there is no difficulty about seeing the bundles for ourselves. We must take a leaf and drop it into a small, well-corked bottle of methylated spirit and leave it there for a few days. The spirit will extract the green pigment from the cells of the leaf, and when we remove it we shall find it has lost all trace of that colour and is quite brittle. We need only hold it up to the light while still wet in order to see, with a lens, the bundles as short distinct lines; but if we want to examine the needle-like crystals of which each of them is composed it will be necessary to use a microscope.

This is by no means the only sort of crystal that is to be found in plants, but the others cannot be seen with so little trouble.

Small as they are we must remember that the mouth of a caterpillar, for example, is but a tiny one, and a meal of Enchanter's-nightshade must be to him pretty much what salad or cabbage would be to us if a few bundles of fine needles, with a sharp point at each end, were mixed in.

Crystals of this kind are called Raphides, from the Greek word for a needle, and another common plant which has plenty of them is the Cuckoo-pint or Lords and Ladies; nevertheless neither of these species entirely escapes being eaten, for each of them has its dependents in the caterpillar world, which must have learnt in some way or other how to get over the difficulty, reminding us of those curious people who leave nothing of a herring but the head, tail, and backbone.

The Cuckoo-pint has furthermore another protection against being eaten off the face of the earth, for it is one of the plants that are poisonous, at any rate to many creatures. The question of poisons is one that cannot be investigated except by the specialist Well-known instances are Hemlock, Belladona, Henbane, and Aconite among many others; but the more important point for the reader to grasp, in view of the co-operative nature of the Scheme of Creation, is the fact that all these and probably all other plants, even the most amply protected and poisonous, have their dependent or dependents who look to them for some, if not for the whole, of their sustenance: poisonous or non-poisonous is, in fact, a relative and not an absolute term.

There is, however, one very easily observed example of a poisonous secretion which characterizes many of our own common plants. Many gardeners know the Petty Spurge as a troublesome weed, and one has only to break it to see the white juice that abounds in its tissues and which, from its resemblance in colour to milk, is known as latex. The resemblance, however, is entirely deceptive, for there is nothing less like milk in taste and other properties than the acrid, burning, poisonous latex of the Spurges, and the immunity from being eaten, which they enjoy, is very easily observed in any garden where they are found as weeds. All the same Spurges contribute something to the general well-being, for the caterpillars of the Spurge Hawk Moth go to them for food.

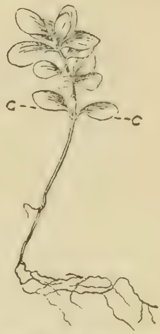


FIG. 12.—Seedling of the Petty Spurge. Reduced $\frac{1}{3}$.

C = Cotyledons.

Latex occurs in many other plants, as, for example, in Dandelions, Wild Lettuces, and Poppies. In the Yellow Horned poppy it is orange instead of white; and in the Wild Lettuce it is about as nasty in every way as one could wish. But there are all sorts of latex, and we must in justice remember that it provides us, from the tropics, with rubber.

A word must be said here about the protective devices against being eaten that are possessed by seedlings. We might expect that tender infancy would have its special safeguards, for we know that in the higher animal world parental care of the young is sometimes as touching as the devotion of the human mother; even in the insect world, as unspeakable in its customs as the Turk, the earwig looks after its offspring, but there is no trace of any such virtue in the vegetable world. It is true that seedling Spurges are as full of latex as the adults, but as a general rule we look in vain for any special protective device. Perhaps we have not looked in the right way yet, for seedlings present to the curious many features which, were their significance understood, might lead us to modify our views.

However that may be there is a more subtle way in which protection is afforded, not to the individual seedling, but to the species. I mean the immense numbers in which they are produced. Plants of one sort or another ripen seeds in hundreds, thousands, tens of thousands, and even hundreds of thousands or more ; that is a fact about which we can easily satisfy ourselves by watching a single individual during a single season. If we count the seeds in one of the long pods of a Wallflower or Stock, and then the number of pods formed by the end of the year, we shall be astonished at the total, even if we take no trouble about selecting the most vigorous individual that we can find.

Let us consider one that produces a modest thousand, and let us remember that in order to keep the number of the species constant only one plant is needed to replace every one that dies. Let us suppose that not more than one per cent. of its thousand seeds produces a seedling, even so we shall have ten youngsters and nine of them may be eaten without doing any harm in the direction of reducing numerical strength, even if the parent should die from one cause or another.

Should the species happen to be an annual or a biennial the parent will die ; but if it be one of the many perennials of our Flora the chances are that it will not, and then the one seed that has triumphed over its nine hundred and ninety-nine brothers and sisters will suffice not only to maintain but also to augment the numbers of its race.

Thus the numerical strength of the seedlings is a great safeguard to the species and we can understand that there is no more need to shed tears over the immensely high rate of infant mortality in the vegetable world than over the reaping of a wheatfield: the green blade and the golden grain alike fulfil one of the alternative purposes for which they were created.

The sacrifice of the seedlings contributes generously to the food supply of small animal life, especially of the snail and slug kind. It is a too common and a very sickening experience for a gardener to find a healthy patch of treasured seedlings thinned off the face of the soil in a single night by a hungry mollusc or two.

Thinning is one of the things that must be done, and in cultivation we do it with our fingers; but Nature relies very largely upon the jaws of her hungry children, and however distressing it may be to the horticulturist such an occurrence as this in the open works for good rather than evil. It feeds the hungry snail which has its own useful part to play in the Scheme of Creation, however much we may discourage him in the garden, for as a matter of fact snails and slugs that indulge in a seedling diet check a numerical increase in this species or that, which, if left alone, would soon monopolize the whole earth.

Thus in view of the fact that the vegetable kingdom has to provide the whole of the food of the animal we can reverence the wisdom which endows its members with the power of producing seeds which must be reckoned in four, five, or even six figures.

Before leaving this subject I must warn my readers against thinking that the protective devices we have been considering have been produced in order to save their possessors from being eaten. It is outside my plan to explain such things as why the Gorse has spines, the Spurge latex, and the Enchanter's-night-shade raphides ; on the other hand, it is altogether foreign to my purpose to convey an impression or suggest a conclusion that the student who pursues the subject will discover to be erroneous. All I can say about this matter now is that the reason of the Gorse being spiny is not to prevent animals from eating it, raphides were not designed to choke hungry caterpillars nor latex to set on fire the mouth of browsing animals : all these things arise from quite other causes connected with the nutrition and general well-being in its own environment of their possessor, and while they serve the useful purpose of protecting plants against the too assiduous attentions of the animal world we cannot allow that they have been called into existence in response to that need.

We must now pass on to what I have called Mutual Competition, that between man and man or plant and plant in the struggle for existence.

(c) *Mutual Competition*

There is no need for me to remind the reader of the various weapons of attack and defence that man uses in warfare or for self-preservation on a smaller scale ; it is more profitable to recall, though I do not propose dwelling upon, the more elevating competition in the realms of Art and Science, Commerce and Trade, the weapons of which are neither fire nor frightfulness, but brains.

We have to consider the competition for root-room and a place in the sun that goes on between plant and plant ; it is so fierce, especially in the seedling stage, that we can no more form an adequate idea of it than of what it would be to be overrun by an enemy invasion.

If we look at one of our country's hedgerows or copses in the spring we shall see thousands of seedlings and youngsters all so close together that certainly only one here and there can possibly grow up, and it would be interesting to know exactly what gives the victory to the survivors.

Let us consider a batch that has happened to escape the attentions of the hungry ones around, and let us suppose that there are twenty newborn seedlings upon a piece of ground large enough to maintain only one adult.

For the sake of simplicity we will assume that all of them are of the same species, the Groundsel or the Petty Spurge, for example, otherwise the problem would be much more complex and difficult to solve, although in the end its solution would be on precisely the same lines.

Barring accidents, one of two things is bound to happen in the ordinary course of nature, either a solitary one will attain the normal size, or if there be more than one, the survivors will be below the normal.

The student can observe what takes place for himself, if he will sow the seeds of some easily grown plant in a pot ; of course he must sow them pretty thickly in order to obtain a crowded crop of seedlings. Peas, Beans, or Nasturtiums will do very well and they can be counted with ease. A single one or two should also be sown in a border, giving ample space to each, and the results should be compared subsequently.

At the start there is no visible reason why any particular one of the batch should win or why the others should perish, but in the absence of more precise knowledge, the victory must be attributed to the better constitution and greater vigour of the conquerors. Overcrowding, especially in the seedling stage, is fraught with many most undesirable possibilities, such as insufficient nutrition which weakens the constitution, lowers vitality, and induces damping off, and those which come off worst for fresh air, light, root-room, and nourishment will be the first to succumb to disease. Their death, however, will ease the strain upon the survivors, and so the struggle will go on until one of them wins or more than one of them remain so evenly matched that they have to share the root-room and other things that are essential for growth and maturity. Thus it comes about that in mutual competition the most effective weapon of the seedling is a good constitution, and it is pretty much the same for our own children too.

Impartial Nature knows no favourites. Now, the difficulty of framing a scientific definition of that or of any other word does not prevent us from understanding its significance clearly or from knowing quite well what we mean by it; and by Nature I mean the all-controlling Spirit of God at work in this world, of all things the most impossible for human definition.

I have subscribed to the belief that all things work together for good, and despite the facts revealed, for example to the student of parasitism, which certainly do not suggest optimism or even unobtrusive happiness, Nature, amid the diversity of her operations, never forgets that the object to be obtained is perfection, the greatest and highest good for her children as a whole, each in its own proper place—vegetable, animal, or human. So she always wants the best plant, the best animal, and the best man to have a good innings, treating all, good bad or indifferent, alike, with uncompromising justice, the best being the one that in accordance with his capabilities contributes the most, not to his own, but to the common good. Money and wealth of one sort or another may do much to help her, but no amount of "the purple" is of any value in comparison with a well-balanced mind and a trained intellect in a healthy body.

We know nothing whatever about mind, intellect, or brains in the vegetable world, not even enough to be quite sure that there are none, but the subject of mutual competition provides ample opportunity for the use of our own. There, are for example, what I may call the big bullying leaves of such low-growing plants as the Hoary Plantain, which is a terrible nuisance on many a lawn. Its rosette of large oval flat leaves simply kills out everything that it covers, and prevents the successful germination of any seeds that may chance to be in the soil beneath.

Then there are the plants that climb by one means or another. Prickles, for example, are useful not only for keeping off hungry animals with soft and tender mouths, but also as organs of support, and the long weak stems of such plants as the Cleavers could hardly scramble about a hedge as they do were it not for the small hooked prickles with which they are beset, although for this end the leaves are useful too as anchors or supports.

Twining is another way in which such plants as the Bindweed and Black Bryony grow up or through a hedge; while the Hop combines both methods, for it makes doubly sure of its hold upon the support around which it twines by the two-pronged hooks which make the stems rough to the touch whether we pass our fingers up or down them.

Again, the White Bryony has its tendrils for attaining the same object, and there are many common plants, such as the Sweet Violet and the Enchanter's-nightshade, which produce runners above ground and underground respectively, and the Bramble that sends out long arching stems which root at the tip and bear firstly leaves and then flowers. Thus, instead of being crowded out they find convenient rooting places and thrive and increase there. The Bramble is particularly interesting because it not only has the arching and rooting stems, but also big bullying leaves which help to anchor it in the hedge, as well as grappling hooks, and I commend it to my readers' notice as one of the most interesting aggressive and successful plants that one can come across in a day's tramp. It has more than once got into my own garden despite the six-foot wall over which it managed to send a rooting shoot.

The last device that I propose noticing is one that will perhaps cause a little surprise, for I refer to the flowers of our woodlands that bloom in the spring.

The difference between a wood in summer and in the winter and early spring is immense. In summer when the fields are green it is shady, if not dark or gloomy, and the plants that have learnt the art of thriving in deep shade are comparatively few. When the trees are bare, there is, on the contrary, light enough for Mistress Flora's business. We have but to think of a wood in spring with its Bluebells and Anemones, and then how badly these same blossoms would fare if they came, say, in July.

Thus the habit of making leaves and flowers and getting all the chief above-ground business done before the wood is shrouded in shade enables these plants to hold their own in places where later blossoms would have no chance at all. By the time that the summer is at its height there is practically nothing to be found of them, without a trowel, except a few worn-out leaves and their fruits and seeds; all the rest is underground, and all that they do until leafing and blossoming time comes round again is to lie low and to make their roots which will be ready when the right time comes to provide next year's leaves with their contribution to the food ingredients; and this brings us quite naturally to the next Factor of Life.

V. Rest

When we have finished our work for the day, the week, or the year, we are glad enough to go to bed at night, to take it as easy as we can at the week-end, and to put work aside altogether during the vacation; in other words, we sleep at night and are more or less slack or lazy during our offtimes and holidays, and except that, as I have said already, there is no such thing in the vegetable world as the sleep of the animals and ourselves, it is very much the same with the plants.

Rest is the fifth Factor of Life.

Now, the great work that plants have to do in this world is to manufacture food while it is day, and if they do not sleep at night they at any rate suspend this, although by no means all, work from sunset to sunrise, and enjoy a partial rest. Moreover they have their longer periods of quiescence too. The Bluebell and many other spring plants, such as Snowdrops and Daffodils, take it in summer; whereas our trees and herbaceous perennials, such as the Oak and the Columbine, hibernate or slack off in winter.

But I suppose that during the whole of the rest of life we never get so much sleep as when we are babies, and similarly in the vegetable world the infant—that is to say, the little plant that is to be found inside each seed—enjoys a period, sometimes longer and some times shorter, which one might almost call uninterrupted repose, until germination starts.

The Nature-student should therefore try to find out when the seeds of the plant he is working at ripen as well as the period that elapses before they germinate.

He could obtain a great deal of information by sowing those of our common wildings as soon as they mature, recording accurately the date of harvesting and sowing, as well as of the appearance of the seedlings above ground; and here I may as well say that if he wishes to obtain results of really scientific value he must take every precaution that his experiments be made under conditions which in all respects approximate as closely as possible to the natural ones.

In Nature seeds seldom germinate on bare soil, and it is therefore wise to cover the earth, after they are sown, with a little moss or stonecrop, which will help matters in more ways than one, especially if we use pots for our experiments.

We have, then, found so far that the essentials of life are pretty much the same for all living things, and I will now very briefly compare our own with that of a plant for the five Factors which we have noticed.

Children are healthy and jolly when they breathe pure air, and, being properly nourished and brought up, are growing into sound and able men and women, adequately clothed meanwhile and sheltered in their homes from the elements. Similarly men and women who are physically and mentally fit and blessed with the right amount of congenial work are very much to be envied. When the right time comes, such children and adults alike drop off to sleep at night and enjoy the relaxation that their leisure hours and holidays afford.

Plants likewise are healthy and beautiful when in the fresh air and properly nourished. Although we must recollect that, unlike ourselves, they do not eat ready-made food, but have to manufacture it for themselves. They, too, grow from pretty youngsters to splendid adults, they are likewise protected according to their needs from the dangers to which they are exposed, and they have their periods of rest and quiescence.

Up to this point, then, we have found that the life of a plant has very much in common with our own life, and before I conclude this chapter I want to point out that these five Factors have to do with and conserve the life of the individual person or plant; they do not of themselves provide for the continuance of the race after the death of the individuals of which it is, at any given time, composed; and since all of us and all the animals and all the flowering plants must die sooner or later, some provision has to be made for filling the death gaps, lest the race should suffer the fate of the individual and die out completely.

In my next chapter, therefore, I shall begin to deal with those Factors that concern and provide for the life of the species from generation to generation.

CHAPTER IV

THE FACTORS OF LIFE—THE PRESERVATION OF THE RACE—MARRIAGE

THE Factors of Life that provide for the continuance and welfare of the race as distinct from those of the individual are but two, both in our own and in the vegetable world.

Our own boys and girls grow up, go out into the world, marry, and in their turn rear the next generation to take their places, and in the course of time to be the fathers and mothers of their grandchildren.

Now, marriage is just as fashionable in the vegetable world as in our own. Plants pass on from infancy to youth, and then to maturity, and the beautiful blossoms that we see in our hedges, meadows, and woods are their bridal robes, while their fruits, whether the dry, uninviting pods of the Wallflower or the tempting Apple, are, so to speak, the nurseries where the vegetable children are to be found, inside the seeds.

This, then, is the sixth Factor of Life; in our own we call it Marriage, and in the plants', Reproduction.

I. Vegetative Reproduction

I have just spoken of the seeds as the Children of the Vegetable World, and while all flowering plants are reproduced normally by them, it is probably familiar enough to most of us that a great number of species have another method as well, a method, too, which has nothing whatever to do with seeds, nor is there anything corresponding to it in the human world.

There are, however, certain animals, lowly in the scale of creation, that increase in number by budding, a familiar example being afforded by the greenfly on our roses and other garden plants.

When we spray them with an insecticide it is true that we kill them, but we do not damage the bud within, hence we find after a few hours that the triumphant youngsters have made their way through the film of soft soap and quassia that covers the body of the dead parent, and so it is necessary to repeat the operation before they, too, have formed an internal bud, if we are to rid our treasures of this troublesome parasite.

The green Hydra, a small creature that can be found in the water among the Duckweed in our ponds, is another example of increase by budding. It can be divided into two or more pieces, each of which will replace by growth the parts that have been cut away by us or bitten off by some natural enemy, as the case may be.

We commonly practise the art of increasing our stock of Geraniums by "cuttings," or pieces of the stem bearing leaf buds, and in Nature a great deal of reproduction is effected by buds of one sort or another that ultimately become detached from the stock and grow up as independent plants.

Reproduction by this means is known as vegetative propagation.

I do not propose going into this trite and fairly well-understood matter, but whatever plant we may happen to select for our Nature-study we must on no account neglect its vegetative propagation, if it has any such power.

Daffodils, for example, are propagated by Bulbils underground; some plants, such as Tiger Lilies and the Lesser Celandine, by other kinds of bulbil produced on the stem above ground; the Sweet Violet and many other plants by Runners above ground; Roses by underground ones called Suckers; and Potatoes by swollen underground stems known as Tubers.

There are other ways, too, which we can notice for ourselves, as, for example, in the Houseleek; but all that I am concerned to impress upon the reader now is (1) that whatever the mode of vegetative propagation may be, it is quite a different thing from reproduction by seed, and (2) that it does not take the place of the latter; those species which have the power possess two methods of reproduction instead of only one.

Let us now turn to the seeds, and see something of the way in which they are produced.

II. Reproduction by Seed

(*a*) *Pollination*

Nowadays, fortunately, and thanks once more to the patient work of our ancestors, things which were hidden from the wisest of sages are the common property of educated men and women, and there are very few, if any, even among those who pay but little or no personal attention to flowers, who do not know something about the necessary preliminaries and perhaps enough about pollination and the part played therein by insects, to enable them to investigate the process, at any rate up to a certain point, in any plant that happens to come under observation. I need, therefore, do no more than remind the reader that he must look for the pollen in the stamens, and that he will find the seedlets, often as small as the head of a little pin, or considerably smaller, in that part of the flower which is called the ovary, that in connection with the ovary is a more or less sticky organ known as the stigma, and that if the seedlets are ever to mature as seeds, some of the pollen grains must be deposited upon it.

The transfer of the grains to the stigma is called simply "Pollination."

Unfortunately, pollen grains are too small to be studied without a microscope, but there are many different kinds of ovary and stigma that can be observed either with the naked eye or with the help of a lens.

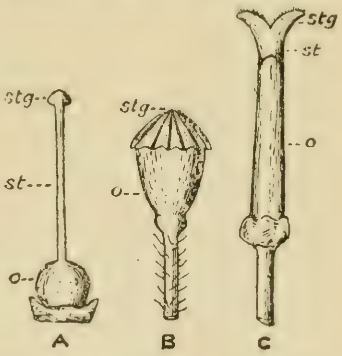


FIG. 13.—Pistil of: A, Primrose, long style, × 2; B, Poppy, no style, × 2; C, Wallflower, short style, × 2. Stg., stigma; St., style; O., ovary.

Sometimes, as in the Primrose, we find that the ovary at the base of the flower has a long pole with a round stigma at the top; the long pole is called the style. Now if we look at the Poppy we shall find a large ovary in the centre of the blossom, its top is vaulted, and instead of a round stigma we have a number of sticky lines radiating from the centre like the spokes of a wheel, but we look in vain for the style, for there is none.

Again, in the Wallflower we have a long thin ovary, and two divergent stigmas topping a very short style.

Now, I do not wish to worry my readers with technical terms, but sooner or later the student will have to know about them, and I want them both to remember that the ovary, the stigma, or stigmas, and the style, when there is one, are known collectively as the pistil. In all the three plants which I have mentioned the pistil is a single undivided organ in the centre of the flower; but there is another kind which is to be found in such well-known plants as the Marsh-marigold, the Bramble, the Yellow Stonecrop, and the less common Flowering-rush. In the first two the number of parts varies, in the Stonecrop it is five, and in the Flowering-rush nine, and in every case each part has its own stigma upon a style that is often minute.

FIG. 14.—Pistil of the Marsh-marigold. × 3.

Stg., stigma; St., style.

We can understand, then, that there is a good deal to be learnt about the pistil from our own wild flowers, and, similarly, we can find a very great range of variety in the form and arrangement of the stamens. Full information can be gleaned from any good text-book, and we should remember that a stamen consists of a stalk called the filament, and a bag at the top which contains the pollen grains, and is known as the anther.

As a rule the stamens are quite separate from one another, as in the Poppy and the Wallflower, although they frequently "adhere" to the petals as in the Bindweed; but occasionally the filaments "cohere," as in the Gorse; while in the whole great family to which the Daisy and the Sunflower belong, the anthers are united or "coherent."

I may add that we use the word "cohere" and its derivatives when dealing with the union of organs that are the same—for example, "coherent" stamens; but when they are not the same the correct word is "adhere." Thus the stamens of the Bindweed are "adherent" to the petals, and in practice this distinction is a decidedly useful one.

I must now say a little about a point of great significance. Most of the plants that we know best, and all those that I have mentioned hitherto, contain stamens and a pistil in every flower; but there are some, like the Vegetable Marrow and the White Bryony, in which no single flower contains both of them. In the Vegetable Marrow we find on one and the same plant some flowers with stamens but no pistil, as well as others with a pistil but no stamens; while in the White Bryony the separation of the two is more profound, for a plant whose flowers contain stamens will have none that contain a pistil, and *vice versâ*, the pistil-bearing flowers are to be found upon plants without any that bear stamens.

Thus there are three main types of plant in this respect:—

i. Those that produce stamens and a pistil in every flower.

ii. Those that produce them in separate flowers on the same plant.

iii. Those which produce them in flowers on separate plants.

As a matter of fact, there are other and more complicated arrangements to be found, but there is no need to worry about them until the reader becomes an earnest student rather than a hobby-botanist. We will confine ourselves to these three types, and before we tackle the question how the pollen grains get to the stigma I must point out that if the pollen of a given flower reaches the stigma of the same flower it is called "self-pollination"; whereas if it reaches that of another flower, it is called "cross-pollination." Of course the other flower may, or may not, be on the same plant, but in either event we will call it cross-pollination, and if we refer to the three types of flower to which I have just drawn attention we shall see that it is only the first that can be self-pollinated, the second may experience either sort of cross, but the stigmas of the third can receive pollen only from another plant.

It is important to realize that it seems pretty certain that cross-pollination is in many ways better than self; it appears also that of the two possible kinds of crossing the benefit to the offspring is greater when the stigma receives grains from a separate plant, instead of from a different flower on the same plant.

It would, however, be extremely difficult to prove either of these statements for ourselves, and we must be content to accept them on the great authority of Charles Darwin, to whose ability and indomitable patience every one of us owes a very great deal more than perhaps any of us realize.

Despite the benefit of crossing we must, nevertheless, remember that self-pollination is better than none at all, and we can find a very great deal of interest in trying to understand the arrangements for ensuring it, in case of need, in any given plant whose flowers bear both stamens and pistil.

I do not, however, intend going very far into the extensive subject of pollination of either kind, because of all the problems of Botany it is, I suppose, the one that has attracted the greatest interest, at any rate so far as cross-pollination is concerned, and consequently so much has been found out and written about it that I need say but little, and I certainly do not feel that I can add anything new or do more than indicate what my readers should try to observe for themselves.

Pollen grains have no power of their own to move away from the anther, but yet they manage to get out of it and on to the stigma. It is true that when the grains are ripe the anther opens, but that does not help matters much, especially when the pollen is too sticky and heavy to fall out or be blown away, as it is, for example, in the White Lily.

Now, the only possible way for us to get about, were we paralysed and unable to move, would be to employ some locomotive agent, and this is precisely what the plànts have to do. If we could neither move nor be moved there would be no alternative to remaining where we were, and as pollen grains cannot move, the help of a locomotive agent has to be invoked.

It is not difficult to observe Nature's locomotive forces. The wind drives the March dust and the October leaves before it, the rivers and streams carry all sorts of things on their waters, and the country teems with insects, birds, and other animals that are constantly moving from place to place, and taking with them, either consciously or unconsciously, various objects, both comparatively large and actually very small.

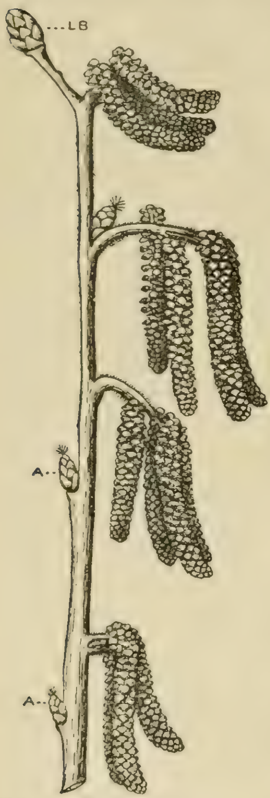


FIG. 15.—Flowering sprig of the Hazel.

A, The pistil-bearing flowers; LB, A leaf-bud. In this sprig the pistils matured before the stamens in the catkins had liberated the pollen grains. Reduced ⅓.

As far as pollination goes these three agents are valuable in different degrees.

The wind acts for quantities of plants with inconspicuous small and scentless flowers, and it is, I need hardly add, an agent for cross-pollination.

We may ignore water altogether, although there are a few plants dependent upon its currents for cross-pollination; they are not, however, likely to come before the notice of any one who is not a professional or a more or less mad enthusiast.

As for the animal world, the chief pollination agents are such insects as Bees, Flies, Butterflies, Moths, and Beetles, and they, too, are essentially cross-pollinators.

(*b*) *Cross-pollination by the Wind*

Our Grasses are the most abundant of our wind-pollinated plants, and no one will deny that their flowers are both small and inconspicuous. The pollen grains, which can easily be shaken out of the dangling anthers, are like so much dry powder, and this should be noted carefully.

The Hazel is another well-known instance, and it is particularly easy to scatter the grains by thousands from the catkins, which we know as "lambs' tails."

The inconspicuous stigmas are less easily discovered, for they are not to be found on the catkins; the illustration, however, will help us out of the difficulty and at the same time afford an example of stamens and pistils being upon the same plant but in different flowers, though probably no one but a botanist would talk about flowers in connection with either the Grasses or the Hazel.

The clusters, into which they are grouped, are rather like small green pineapples with a crown of crimson stigmas instead of leaves, and if we are to satisfy ourselves that they really do produce the nuts, it will, of course, be necessary to watch them and to note the changes that take place from time to time.

(c) *Cross-pollination by Insects*

Let us now turn from the small, inconspicuous, scentless flowers of the wind-pollinated fraternity to the bright blossoms of such plants as the Poppy and the Corn Convolvulus, which woo, not the wind, but the insects.

The former pays its guests for their services by feeding them with pollen grains which it produces in great abundance; whereas the latter tempt them with wages in the form of honey, brought to their notice by bright colours and sweet scents. I must point out, too, that the grains, which are not meant to be blown away, are adhesive instead of like dry dust, and this is very frequently the case with insect-pollinated plants.

Now, I do not think it would require much argument to persuade us that both the wind and the insects effect cross-pollination; but, on the other hand, it is quite certain that with the plants, whose flowers bear stamens and pistil in one and the same blossom, the insects at any rate might be responsible for a good deal of self-pollination as well, and we should, therefore, in view of the greater value of a cross, be on the look-out for any arrangement calculated to prevent the former, at least until there has been time enough to afford opportunities for a cross; for if that does not take place—if, for example, a flower is not visited by the insects—self-pollination is preferable to none at all.

The two chief ways in which it is hindered until it becomes desirable are by separating the stamens from the stigma, either in time or else in space.

A good example of the former is afforded by the Foxglove, and also by our Christmas Roses and Columbines. In the first the anthers open before the stigmas mature, so that there is a good chance of the pollen grains of any given flower being carried off by Bumble Bees before its stigmas are ready to be pollinated. In the other two, it is the stigmas that mature first, and an insect which visits either of them when the blossom is freshly opened must pollinate it, if at all, with grains from another blossom.

Separation in space occurs as commonly as separation in time. If we examine a Tulip we shall see that the stamens and the pistil are so far apart that there is not much chance of the pollen grains getting on to the stigma, especially as the insect visitor intrudes his person between the two, and so will touch each with the opposite side of his body.

Thus we learn that the devices in the vegetable world for preventing or delaying self-pollination come under four heads: the stamens and pistil may be on separate plants, or in separate flowers on the same plant; again, where they are both found in the same flower the separation may be either in time or in space, or, indeed, in both.

(*d*) *Self-pollination*

Before I finish with Pollination, however, I must say a little about the devices for effecting self-pollination, in the event of a cross having been missed; but they are so many and so varied that I can only refer to a very few of the commonest of our wild or garden plants.

We have just learnt that where it is not an absolute impossibility self-pollination is hindered by the separation of the grains and the stigmas, and we must now see how the hindrance is removed. The Buttercup is a plant which ripens its stigmas first and its grains afterwards; but there are quantities of others in which the grains are the first to mature, and the Ragged Robin is a good example.

If we watch a blossom of either of these plants we shall see that there are two well-marked stages, in the first only one of the two actors comes into play; but the point is that, in each case, that one still goes on playing its part after the other has matured. In the first stage, therefore, cross-pollination is the only possibility; but in the second there are good chances of self-pollination too.

It may, however, occur to the reader that, although the separation in time has come to an end, the grains and the stigmas are still separated in space, and this is quite true. Let us see, then, how the space is bridged, There are many different ways in which it may be done, but I propose to indicate only in a general way what is carried out in Nature, with an almost incredible amount of variety in detail.

The pollen grains sometimes reach the stigma of their own flower by falling upon it, as we can understand readily if we turn to a Buttercup or the blossom of a Lilac; or, again, they may be knocked on to it by an insect.

But they may fall on to the corolla, and they often do; two examples will suffice. In the Ragged Robin there are plenty of grains to be seen with a lens on the petals, and in the last stage of the flower the stigmas grow in amongst them, and so self-pollination comes about.

In the Corn Convolvulus we can find grains upon the corolla, but here the device is a different one. As the blossom withers it closes up again into a crumple, and so the inside of the petals, where the grains are, is brought into contact with the stigmas.

Most people know that in the Primrose there are two kinds of flower: one with a long style and the stamens below the stigma; the other with a short style and the stamens above it. In the latter some pollen grains may, of course, drop or be knocked on to the stigma; but self-pollination is quite possible in the other kind too. Instead of withering into a crumple like the Corn Convolvulus, when the right time comes, the corolla, while still fresh, drops out of the calyx whole, and if we look at it we shall see that the stamens adhere to it. Now, the style and the stigma do not drop off until after the fall of the corolla, and so in the long-styled flowers the stamens are dragged over the stigma and effect self-pollination in that way; it has nothing to do with the fall of the grains. Movement, of one sort or another, quite independent of gravity, is a very common device for self-pollination, and, as a matter of fact, in the Ragged Robin and the Convolvulus, too, self-pollination depends, in the last instance, not upon the fall of the grains, which is only a preliminary step, but upon the action of the stigmas in the one and of the corolla in the other.

But there are other plants in which it is neither the stigmas that grow, nor the corolla that moves, but the stamens at last touch the stigma, and that very common pest, the Chickweed, is one of them. The flower is small, so it will be necessary to use a lens in order to make it out. We can, however, see the same thing quite plainly and unmistakably in some of the Lilies which are commonly grown in our gardens. In the Turk's Cap and the White Lily the stamens, when the blossom first opens, are a long way from the stigma, but before it withers we often find that one of them has moved forwards, with the result that its pollen-laden anther lies right upon the sticky stigma, and this brings us to one of the most interesting of all the methods of self-pollination.

The Wood-sorrel is one of the daintiest of our spring blossoms, or we may turn to the Sweet Violet, the Wood Violet, or the White Deadnettle, for in all of them, and in some other plants as well, there are two kinds of flower.

There is the one that everybody knows and sees; but the other never gets beyond the stage of a tiny bud, nevertheless it performs the essential duty of a flower, which is, of course, to produce seeds.

If we have the patience to watch these buds, which in the Sweet Violet are to be found hidden away at the base of the leaves, on short stalks, and in the Wood Violet are on the leafy flowering shoot, we shall learn that although they never blossom they produce fruits and seeds; and if we are keen we shall open some of them for ourselves and try with a lens to see the pistil in the centre and the stamens pressed around the stigma, so as to make sure that self-pollination shall take place. It appears that the Violet's plans for a cross are not very successful; but, on the other hand, those for self-pollination are about as certain as they can be. Moreover, there is no waste, nor are there any wages to be paid—the grains cannot be lost from the closed buds, and there are no insects to be fed with pollen or honey in return for their services.

FIG. 16.—Seed-producing bud of the Wood Violet. Natural size.

III. THE DEBT OF THE VEGETABLE TO THE INSECT WORLD

This great subject of Pollination, or rather of Cross-pollination, illustrates in a very happy way what I mean when I say that the Scheme of Creation is a co-operative one. I emphasized, when dealing with Nutrition, that it is the plants that provide the animals and ourselves with food and keep the air duly supplied with oxygen for the purposes of respiration ; but now we begin to see the other side of the account, we realize in this, the sixth Factor of Life, that the debt is not all on one side, but that, in their turn, the bright blossoms which add so much to the pleasure and beauty of life depend for their continuance from generation to generation upon the insects. In the caterpillar stage they eat the leaves, or other parts of this plant or that, but they make up for it by pollinating the stigmas now that the crawling grub has changed into a beautiful moth or butterfly, or perhaps into a beetle, a fly, or some other insect.

I do not mean that if there were no insects there would be no plants ; but I do mean that in all probability there would be no bright blossoms and no sweet perfumes, but only such wind-pollinated flowers as those of the Grasses, the Hazel, the Sedges, and the Pine.

Thus, while the animals depend upon the plants for breath and food, they render good service in return in the important matter of reproduction, as well as in other ways which will come before our notice in the sequel.

We must pass over all those complex happenings between the pollination of the stigma and the ripening of the seeds of which we can see but little and make out nothing without a great deal of hard work and training. What we can observe with the naked eye, however, is full of interest. We can watch the small pistil of the Wallflower grow into the long pod, full of seeds, and see it split open to allow of their being blown away, or the pistil of the Bramble turn into the Blackberry ; we can witness the development of Peas and Beans, Apples and Cherries, Acorns and Hazel-nuts, Poppyheads and Nasturtium fruits; but we shall not be able to understand very much about how it all comes about without resort to the laboratory and the microscope.

Curiosity, no doubt, will stimulate investigation, and the student will soon discover first-hand a very great deal more than he could glean second-hand if I devoted a chapter or two to the subject.

I propose, therefore, saying nothing more about this factor of life except that, as we shall see in the next chapter, the seventh and last is like unto it in so far as this, that the debt which the animal world owes to the vegetable is, in its satisfaction, reduced to the vanishing point.

CHAPTER V

THE FACTORS OF LIFE—THE PRESERVATION OF THE RACE—THE CARE OF THE CHILDREN—THEIR PATRIMONY AND TRAVELS

WE have now to find out a little about what plants do by way of providing for the well-being of their children and giving them something wherewith to start life on their own account.

To my mind, this, the seventh Factor of Life, the Care of the Children, is, from the human point of view, at once the most interesting and attractive of them all, and those of my readers who know, or have known, the blessings of a happy home, a good wife or husband, and healthy children in the nursery or at school, will, I am sure, agree with me cordially.

Our children have not only to be clothed and fed, or in a word, brought up, but afterwards they have to be started in life on their own account. Similarly the children of the vegetable world must be brought up and sent forth to play their part in the Scheme of Creation.

We have to provide for our own children until they can fetch and fend for themselves, and so do the plants; again, if we are good parents, we do our utmost to give them the best chances of success on their own lines, and so do the plants. I imagine that their treatment of their children furnishes valuable evidence as to the character of human parents: let us then turn to the seed for information about the Vegetable World.

I. The Seedling's Patrimony

If we take a seed of a Columbine or a Monkshood and plant it in the soil, sooner or later we shall find that it produces what we call a seedling. Inside the seed is a tiny little plantlet, known as the embryo, that develops and grows into the seedling which we see in the illustration.

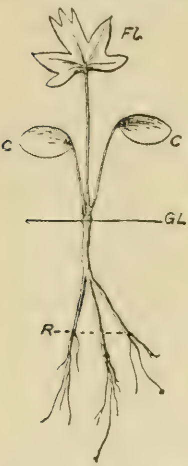


Fig. 17.—Seedling of the Monkshood. Reduced 1/3.

C, cotyledon; R, root; FL, foliage leaf; GL, ground line.

Now, growth is the result of adequate nutrition, and we may legitimately wonder where the embryo gets its food from. It is easy enough to understand how the seedling itself manages, because it is provided with roots, and its green leaves are able to manufacture what is needed; but where did the food come from that enabled the little snippet of an embryo inside the seed to develop a long root and green leaves?

In order to understand the answer to this question we must cut a seed open. We shall then see the hard seed-coat on the outside and the embryo at one end, though it may take some finding; all the rest is composed of a mass of cells which fills the whole of the rest of the space inside the coat.

We can verify this much for ourselves without any difficulty, but until the student has learnt enough to be able to prove it to his own satisfaction he must take my word for it that the mass of cells contains a reserve of food upon which the embryo draws as it grows into a seedling. And that is how plants provide for the adequate nutrition of their children until they are able to look after themselves; they do not all do it in exactly the same manner, but, in one way or another, the parent provides its offspring with enough to last until it is strong enough and big enough to manufacture its own supplies. In the seed of both the Columbine and the Monkshood, as well as of a great many of our common plants, the embryo remains tiny and is surrounded by the food reserve; but in others, as, for example, the Sweet Pea and the Charlock. it is very much larger, so large that it fills up the whole of the interior of the seed, and the food is stored, not in a mass of cells outside it, but inside its own body. In this sort of seed the nutriment is absorbed into the body of the embryo during the process of ripening, and is held in reserve in order to be digested and assimilated when germination commences, whereas in the other sort it is not absorbed until germination takes place. In either event, however, the food has been manufactured by the parent and handed over to the seed for the use of the youngster; it is, so to speak, its patrimony.

FIG. 18.—Seed of the Monkshood (in section). × 3.

Sc, seed-coat; E, embryo, FS, food supply.

That is all I need say about the provision that plants make for their children during their helplessinfancy, and I can now pass on to the opportunities provided for a successful career, with, however, a recommendation that the student should always try to find out which of the two kinds of seed is produced by the plant he is studying. It is not always easy, especially when they are very small, but that is no reason why he should not try successfully to do so.

II. Seed-dispersal

(*a*) *Its Object*

Good parents in the human world do their utmost to give their sons and daughters the very best chance they can afford or command, and not only by educating them discreetly and providing them with money. They strive for all they are worth to place them well, and in the vegetable world also plants adopt means to provide their seeds with a chance of successful germination, or to place them where they will be able to grow, and in due course to bring forth their own offspring.

This subject of placing the seeds favourably is known as seed-dispersal, and I wish I could treat it as fully as I should like; in practice, and for the sake of convenience, one frequently refers to it more shortly as "dispersal."

As a matter of fact, the dispersal-unit, or the thing actually dispersed, is frequently a good deal more than the seed pure and simple; for example, a grain of wheat is really a little dry fruit containing a single seed. We need not, however, go into such a question here, but for the sake of simplicity I shall speak of the seed, or the fruit, whenever by so doing I can, without harm, avoid introducing another technical term merely for the sake of a more or less pedantic indulgence in terminological accuracy. If one uses such terms at all, accuracy is, of course, indispensable, but it is sometimes wiser to give them a very wide berth indeed.

Once more, as when dealing with pollen grains, we must realize quite clearly that seeds have no power of themselves to help themselves, they cannot get about from place to place without assistance ; on the other hand, it would never do if they merely fell from the parent plant to the ground and remained there, for then we might find hundreds or thousands or tens of thousands of seedlings all trying to grow where there would be room only for one or two adults. If a seed is to have a fair chance it must reach a place for its germination where it has enough room in the soil for its roots and in the air for the rest of its body, its stems leaves and flowers ; and the question is, how do seeds, which have no locomotive powers at all, manage to get about and to find a suitable spot ?

When dealing with Protection I pointed out that the object is not to prevent every plant from ever being eaten at all, but that a sufficient number should be preserved to feed the hungry animals and to provide for the next generation of plants as well ; and so in dispersal, the object is, not that every seed should find a suitable spot, but that a sufficient number should survive to provide the plants of the next generation, and it is important to bear this fact in mind.

We must remember that in the Scheme of Creation seeds are meant not only to replenish the supply of green things that keep the atmosphere pure, but also to provide sustenance for the animal creation, including ourselves. Hence the numerical profusion is not by any means wasteful ; it is, on the contrary, utilized for maintaining life on a higher level—to wit, insects and birds, four-footed and other animals, as well as human beings.

One sometimes hears people talk about the wasteful ways of Dame Nature. Personally, I think that that is a very mistaken view; but the question is largely one of those interesting side issues which my readers must follow up for themselves in their own way as opportunity offers. I want them, however, to be not only enthusiastic but also reverent students of Nature. We have been taught in our youth, and as life progresses our own experience confirms the wisdom of, the four words, "Waste not, want not," and Nature does not set the bad example of reckless prodigality. In pollination thousands of grains are produced for every one that fertilizes a seedlet, but the remainder are not wasted, since they pay, so to speak, the working expenses of the pollination mechanism. The seeds which fail to develop into plants are not wasted either, for if, instead of feeding the hungry, they perish and die, even so, like the pollen grains that fall to earth and rot, they return to the soil and the atmosphere those elements of which they are composed and which are thus put at the disposal of other organisms. Change and decay are always in process, but nothing in the world can ever be destroyed in the sense of being annihilated or utterly useless for evermore. Decay and putrescence, especially of animal matter, are indeed unattractive to us, but we should realize that, like respiration, they help to keep the atmosphere supplied with carbon dioxide which is so indispensable for plant nutrition. Every organism that breathes exhales this gas and so helps to replenish the supply, and the animal world effects a further reduction of its debt to the vegetable by the decay of the dead body.

We have already noted the three great locomotive agents of Nature—wind, water, and the animal world—and we shall find that all of them are operative in the great work of seed dispersal. I will give a few instances of each which can be verified with very little trouble.

(*b*) *Dispersal by the Wind*

The plants whose seeds are helped along by the wind are legion, and every one knows the flying fruits containing one seed apiece of the Dandelion, the Thistles, and the Groundsel. Again, there are the seeds of the Willow Herb, which is such a pest as a weed in many gardens. Fruits and seeds of this sort are provided with parachutes which enable them to float in the air while they are being blown about. Another device for catching the wind is the production of thin, flat, more or less disk-like seeds or fruits that are blown about almost as easily as confetti. Such fruits are to be found on our Elm trees and Birches, while flat seeds are produced by the Stock and the Wallflower, the Yellow Toad-flax and the Rattle.

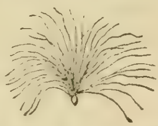


FIG. 19.—Seed of Willow Herb. × 1½.

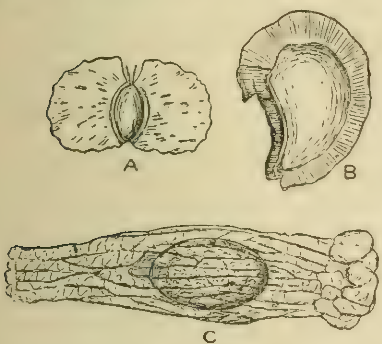


FIG. 20.

A. Fruit of Birch, × 3; B, seed of Yellow Rattle, × 5; C, seed of Bee Orchis, × 80.

The membrane which forms the margin of such flat seeds and fruits is known as the Wing, and in some of our trees it is developed to a much greater extent than even in the Elm. Good examples that deserve consideration are the fruits of the Sycamore, the Maple, and the Ash, and the seeds of the Pine. We may with advantage drop any one of them out of a top-story window on a windy or even on a calm day in order to see what happens.

I am sure that their performance will afford both pleasure and surprise. The seed of the Pine, for instance, will spin round and round as it falls to earth; this, of course, extends the time taken over the journey, and on the wings of the wind such fruits and seeds will travel a considerable distance before coming to rest.

Or instead of being large and winged the seeds may be so small as to fly like dust before even a gentle breeze; our native orchids and some other plants of different families are possessed of gauzy seeds of great beauty, which, however, are so small as to require the use of the microscope for their adequate appreciation.

There is another method by which plants take advantage of the wind, and it can be seen equally well in the Scarlet Poppy, the Columbine and the Ragged Robin. Their fruits are borne upon long flexible stems, and they open respectively by small pores, slits and valves to allow the seeds to escape.

This, however, does not at first sight seem to be a very happy device, since in all three cases the opening is at the top, and seeds do not rise or fall upwards. But as the fruits sway too and fro in the wind and catch in the surrounding herbage the seeds get such a shaking that they are shot or jerked out and scattered broadcast.

It should be noted that for a great many plants whose fruits open for the liberation of the seeds, dehiscence does not take place in wet weather, but only when the parts concerned are quite dry, and there are many species which do better than this, for their fruits, after having opened in the dry, close up again in wet weather, or when the air is very damp, and the seeds which they still contain are thus protected from being clogged by the water which might otherwise gain admittance.

The student should always note these points, testing the fruits of the species with which he is engaged: he will find instances of closing in the families, among others, to which the Poppies, the Ragged Robin, the Bellflowers and the Snapdragon belong respectively. Such observations should be made whenever possible on freshly opened fruits, as the power seems to be sometimes shortlived owing to abrasion or injury of the tissue concerned.

There is, again, a small number of plants of quite peculiar interest in that, when wetted, their seeds emit a mucilage which causes them to adhere to dead leaves and other *débris*; only a few instances have been recorded so far from our own Flora, but, fortunately, they include two of our commonest weeds—the Shepherd's-purse and the Groundsel, whose parachute has already been noted—so the reader can very easily satisfy himself by experiment, and perhaps make desirable additions to the records.

Considerable care, however, is necessary when testing seeds for adhesiveness so as to be quite sure that it is not the leaf that adheres to the seed instead of the seed to the leaf. I remember experimenting with those of the Bird's-eye and some leaves that I had brought home which were lying about the plant. The result that I obtained was that on one and the same leaf some of them adhered, whereas others did not; this was the last thing I should have expected, and, moreover, the previously recorded results of a much more experienced observer were that they were not adhesive at all. A second trial of my own with another leaf entirely confirmed his observations, and an examination of the misleading leaf revealed thereon a fairly broad slime track, left no doubt by a good-sized slug. It had become sticky when I moistened the leaf, but, at any rate, it was worth while learning that slime tracks play this subordinate but useful part in seed-dispersal, and we should remember that a vast amount of it is effected by the co-operation of the wind and dead leaves.

Whether wet or dry, adhesive or not, seeds are thus scattered broadcast over considerable areas, even such large ones as those of the Yellow Flag, which emit no mucilage; they, nevertheless, adhere to leaves so long as they are wet, and even when leaves and seeds are both dry they are blown along together for considerable distances. I have, for example, found the Yellow Flag's many yards from the parent plant, and under circumstances that left no doubt about the part played by the leaves.

I shall have to refer again in the next chapter to the adhesive powers of seeds, and then we shall understand their use at another equally important stage in the life-history of the seed.

Lastly, the wind is responsible for a good deal of short-distance dispersal over the water as well as over the land. In still waters we can find many that float on the surface, although, as a rule, only for a comparatively short time, and while floating they may be blown by the wind for a considerable distance. It is interesting to collect a handful of *débris* from the margin of a pond, lake or river, if not altogether easy to supply the names of the plants to which the seeds that it contains belong: a good deal, however, can be learnt by making the attempt, and knowledge so acquired has the great merit of being very apt to stick.

A gentle wind or a breeze over a lake will effect a good deal of dispersal for such seeds as float, while a gale which lashes its waters into foam and spray will carry comparatively large ones a considerable distance beyond its margin, though, of course, by no means always to a suitable spot.

(c) *Dispersal by Water*

In the examples that we have just noticed it is the wind and not the water that is the motive force, but water is by no means to be despised as an agent by any one who studies dispersal. There is not very much to be said about it within the limits of this book, which do not include dispersal by ocean currents over hundreds or thousands of miles; but it plays a very considerable part in short-distance and local dispersal within the limits of our own islands.

Running water, for example, is capable of much greater things than the wind blowing over a pond or lake, and the seeds of some plants are carried long distances by streams and rivers. I referred just now to the Yellow Flag, which is common enough to be very well known. Its large light seeds are capable of floating for months. They ripen in the early autumn, but they do not, as a rule, germinate until the late spring, and sometimes not for eighteen months or two years, during the whole of which time they may remain afloat, so they stand a good chance of being carried many miles on the bosom of even a very slow stream.

A heavy fall of rain will wash many seeds down a slope, even a gentle one, and the cascades which are such an attractive feature of some of our hilly or mountainous districts after a downpour, are, within their own limits, as effective as the rivers, and very much more rapid.

I drew attention in the last section to the fruits which open in dry weather and close up again when it

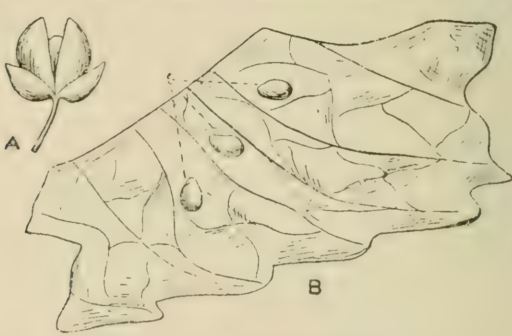


FIG. 22.—The Brooklime.

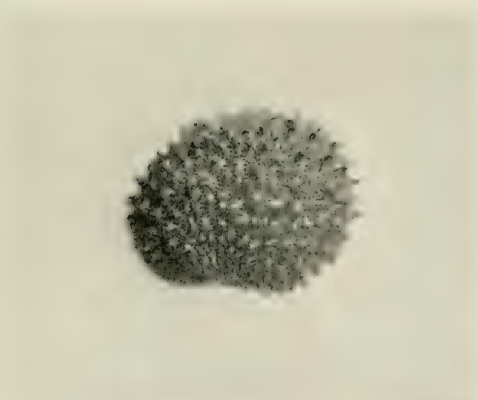
A, the fruit after dehiscence, × 3; B, a fragment of a Willow leaf with three of the seeds adhering to it; S, seed. × 5.

is wet: there are, on the other hand, a few that remain closed, or do not open sufficiently widely when dry to give the seeds any chance of escaping. The Self-heal and the Brooklime respectively afford a common instance, and, although they differ very widely in detail, neither of them parts with its seeds

PLATE II.

I.

II.



I. Fruits and Seeds of the Yellow Flag. $\frac{2}{3}$ natural size. Fig. 21.
II. Seed of the Ragged Robin. $\times$ 30. Fig. 26.

except in wet weather. The seeds of both these plants emit a mucilage when wetted, and they are small enough to be washed away easily by rain runnels, which play a very considerable part in short-distance dispersal: they begin their career with a good bath, and end it, perhaps, after a long journey through the air, adhering firmly to a flying leaf.

(*d*) *Dispersal by Animals*

Of all the agents for dispersal, animals, no doubt, offer the most extensive field for observation: many different kinds carry about seeds in incredible quantities, and it is not at all difficult to make observations of the greatest interest.

If we live in the country and have in our home a cat that is given to hunting at night, we shall be surprised, on applying a comb to his coat, to find how many seeds it contains. In my own small garden there are three weeds which I root up whenever I see them. I could not understand how they got there until I combed the cat, but then the puzzle was a puzzle no longer. They are the Enchanter's-nightshade, the Cleavers and the Yellow Avens, and a glance at the illustration will help us to understand the matter. I get them regularly every year, simply because the cat goes hunting in the places where they grow and brings them home in his coat, from which they drop or get rubbed off here and there, as he enjoys a roll in the sun, on one or another of the flower borders. It is, of course, the hairs and hooks which cause them to stick in his fur.

Again, if we have a dog of healthy instincts that comes home sometimes covered with mud, and if we pick the pellets off his coat and keep them moist in a saucer, we shall be quite surprised at the number of seedlings that make their appearance; or we can try some mud scraped off our own boots after a ramble.

Now, what is true of ourselves and our domestic

Fig. 23.

A, fruit of Enchanter's-nightshade, × 6; B, fruitlet of Yellow Avens, × 9; C, hooks on fruitlet of Cleavers, × 35.

animals, in this respect, is also true of our wild animals, which are not so easy to observe or to catch and comb, but I once found the seeds of several different kinds of plants in the fur of a dead water vole.

Our cat, however, teaches us one of the uses of the hooks and other clinging organs of fruits and seeds, while our dog or our own boots will help us to understand the very great value of mud in the dispersal of seeds: and I may add that the adhesive power of mucilaginous seeds enables them to stick not only to dead leaves, but also to the fur and feathers of animals and birds, and so to get about from place to place at their expense.

In all these cases we should note that the animals are unconscious agents, they are not aware of what they are doing; but there are others in which they go for the fruits quite deliberately, familiar examples being the berries that are eaten particularly by birds, and acorns beloved by the Jay. Until the seeds are ripe, berries are attractive neither in colour nor taste, but when they have matured, those of the Hawthorn, for instance, are conspicuous from a distance as well as soft and tempting.

At first blush being eaten does not seem to be quite the most fortunate thing that could happen to the seeds, but they are, nevertheless, too well protected by the hard exterior to be ground up by the bird's gizzard and digested, so they are subsequently ejected from the body perhaps a long way from the place where the berry was produced: they may be regurgitated after the meal and then got rid of through the mouth, but if they pass through the body *viâ* the alimentary canal, and fall to the ground they will do so under circumstances obviously favourable for germination.

Beech nuts are also interesting fruits: to see them lying in great numbers beneath and around the parent tree one might almost exclaim with Keats—

> "And great unerring Nature once seems wrong."

one might almost think that she had forgotten the proper thing to do.

However, mice and squirrels, among other animals, like a diet of this sort, and, of course, the nuts that they eat do their work in the world by feeding the hungry instead of producing more Beech trees. But both these animals indulge in the provident habit of storing up food, and while they may forget the hiding-place, neither of them can by any means be sure of living long enough to make use of the store, hence a certain number of them remain where they are buried, and we all know what happens to sound seeds under such circumstances.

The Beech nut is particularly interesting because, if we pick up some of the fruits in a damp wood we shall find it extremely difficult to force open the four woody valves that enclose, as a rule, two nuts ; we need not, however, trouble about that, for all we have to do is to put them on the mantelpiece. As they dry the valves will open widely, and if we then put one of them into a cup of water it will not be long before they close up again. This always strikes me as a delightful contrivance, for when the fruit is carried off in the damp autumn and stored in a dry place the nuts will get loose, and afterwards the rains will supply the moisture necessary for germination.

But probably the most interesting of all the creatures that carry about seeds are the ants.

There are many of our common plants which depend very greatly upon their services. I find them in my garden a great nuisance in this and in other ways, although my interest in them is very much greater. One of my worst weeds is the Petty Spurge, and, thanks to the ants, it appears in all my beds and borders. The Sun Spurge is another example. The seeds of both species can be harvested in thousands from waste or badly cultivated land, and if we examine them we shall find that they are provided with a small but conspicuous fleshy knob, and this is the bait that attracts the ants.

FIG. 24.—Seed of—
1, The Petty Spurge. ×15.
2, The Sun Spurge. ×6.
B = the bait.

If we do not succeed in catching them in the act, all that is necessary is to take a few seeds and lay them on the ground where they are foraging, and we shall soon see what they do.

Some of them will perhaps nibble at the bait and then run off, another will seize one in its jaws and retire into a little depression in the soil in order to enjoy a meal, leaving the seed behind when it has had enough: others will grip a seed apiece firmly by the bait and disappear with it into the nest.

It is difficult to be quite sure about what happens in the last case, but it is at any rate more than probable that the bait is nibbled away inside the nest, and that the seed is brought out again afterwards and left somewhere on the soil in the near neighbourhood.

I want to draw particular attention to the part played by the ants in the matter of seed-dispersal, more especially because comparatively little has as yet been found out about it in this country, and it is not very difficult to discover a great deal more; such knowledge would be extremely useful in helping agriculturists as well as Botanists to solve some of their many problems.

(*e*) *Self-dispersal*

I have chosen the Spurges out of a host of ant-dispersed plants because they also belong to a small class whose members are very remarkable in another way.

With but comparatively few exceptions there is no mechanism in the plant itself for dispersing the seeds; in the Groundsel they are blown away by the wind, in the Brooklime, the Birds-eye and other small-seeded, low-growing plants they are washed out by the rain, in the Hawthorn they are carried off by birds, and in the Beech tree they merely drop to the ground, but in the Spurges they are dispersed or put at an appreciable distance from the parent plant, in the first instance, by the plant itself.

In order to see how it is done we must watch, and we shall find that when they are ripe the small three-cornered fruits suddenly explode and scatter the three seeds contained in each a short distance.

Now, there are quite a fair number of wild plants that shoot their seeds in one way or another. I shall however, be dealing pretty fully with the Cranesbills later on, so I will not spoil the reader's pleasure in finding out for himself the exact method adopted by the Wood Violet, the Box, the Cuckoo-flower and the Gorse: all of them are quite common and well known, although probably the fruits of the Box are not so easily accessible as those of the other three.

FIG. 25.—Seed of—
A, Wood Violet. × 4.
B, Gorse. × 5.

In all these dispersal in the first instance is effected by the plant itself: we have learnt already that in a vast number of cases provision is made for self-pollination, and we must not forget that there is such a thing as self-dispersal too, although only for a short distance and in comparatively few cases.

It is rather noticeable that seeds that are shot are not infrequently provided with a bait to tempt the ants; for example, out of those that I have mentioned five are baited, namely, the two Spurges, the Wood Violet, the Box and the Gorse.

This brings me to the last thing that I propose saying about seed-dispersal, although as a matter of fact there are a great many others that I have ignored altogether.

The Gorse will illustrate my meaning. In the first instance the seed is shot away by the explosion of the pod, its bait tempts an ant to carry it off and enjoy a meal; it may then come in for a heavy downpour and be washed down a slope, and it is quite possible that it may subsequently be blown a considerable distance among dead leaves and then picked up in the wet mud by a passing animal and carried a very long way from its parent before it germinates. We must, therefore, never think of the seeds of any plant as being dispersed only in one way, for it is quite certain that at different times the same seed may be helped along in its travels by several agents, and I am quite sure that the student will find no more engrossing and interesting subject for investigation than that of seed-dispersal, especially if he realizes when giving his attention to it that it brings before his notice one of the several ways by which, in the co-operative Scheme of Creation, the animal world ministers to the essential needs and necessities of the vegetable. It will not only help him to become a competent Botanist and

Naturalist, but, what is of infinitely greater importance, it will ensure an intelligent, sympathetic and appreciative realization of the great principle of mutual help upon which life and progress, individual, family, social, national, international and spiritual, depend, from moment to moment.

Such realization of our absolute mutual interdependence should reveal to him, if not more fully, certainly as fully as anything else can, what is meant by losing one's life in the attempt to save it, and how, with no thought of saving it, that life is preserved which consists not in self-seeking, display, pride and luxury, but in self-renunciation, modesty, humility and faithful service for the common good.

CHAPTER VI

THE FACTORS OF LIFE—THE PRESERVATION OF THE RACE—THE CARE OF THE CHILDREN (*continued*) SETTLING DOWN FOR LIFE

EFFICIENT dispersal is beyond all doubt a matter of paramount importance in the Vegetable world, but it is by no means the only necessity which has to be provided for if the seeds, when they have reached a suitable spot, are to germinate thereon and the seedlings to attain to maturity.

If we take a few seeds of the small Garden Convolvulus, which unlike the Bindweed and the Corn Convolvulus is not a twiner, and if we place some of them on the soil and others about an inch beneath it in a separate pot, we shall find that in the latter case the seedlings do all right, whereas in the former the great majority perish in early infancy, their death being due to one or more of the following causes.

The supply of surface moisture may prove to be insufficient for such comparatively large seeds even when they are kept well watered; or the radicle, which is the first rootlet, may fail to penetrate the soil; or the cotyledons, or seed leaves, which are in most species so different from their successors, may not be able to get free from the seed-coat: and for successful germination every one of these three necessities must be satisfied, while in addition the seeds must be kept at an appropriate temperature. In order to obtain some evidence of my own I experimented one summer with seeds of various sorts and sizes, and I found that with the smaller seeds of the Pink and Stock, which by the way are also flat, the radicle starts all right on a moist soil, although it may fail to find a soft spot or a tiny crevice into which its tip can grow.

If it be lying loose on the surface and does not produce roothairs in sufficient numbers to fix it in the soil, it cannot get the requisite purchase, and sooner or later it will wither and die.

Even if it succeeds in finding a friendly crack and in inserting the tip, the next difficulty is with the cotyledons, and for many but not all seeds it is by no means easy to get them free from the coat unless the latter be fixed.

Some seem to get on, provided the radicle manages its business properly, and especially those of the family to which the Stock belongs, and of which Mustard and Cress are familiar examples. If we sow seeds of either of these two, as is commonly done, on a piece of damp flannel we shall be able to see how the roothairs fix the radicle and how the cotyledons divest themselves of the seed-coat, whereas others, such as Violets and Convolvuluses in addition to the Pinks, come off very badly indeed in the struggle.

Now, while the radicle is of course entirely indispensable, the cotyledons are so important for the adequate nutrition of the seedling that if we cut them off it perishes inevitably and if we remove only one the chances of its survival to maturity are jeopardized.

As far as getting free from the seed-coat is concerned, I need hardly add that I am speaking only of those seeds that send their cotyledons above ground, where they become green and set about manufacturing food, for it is well known to many people who are gardeners rather than Botanists, but who perhaps have not thought about its significance, that in some species their safety is much more secure because, instead of emerging from the coat, their duty is to remain inside and deal with the food supply that has already been provided by the parent plant: Wood Anemones, Sweet Peas, Acorns, Crocuses, Daffodils and Scarlet Runners are of this sort, but not French Beans. We understand, then, that in addition to warmth and moisture it is often a matter of vital importance, especially for seedlings with green aerial cotyledons, for the seeds to be firmly anchored in or covered over by the soil, and there are various interesting ways in which this is managed, that can be observed without difficulty. The hooks, for example, upon the fruits combed out from the coat of the Cat are useful; they help to anchor the seed which may be pressed into the soil by heavy rain or by being trodden in or rolled upon: they also collect small particles of dust and thus aid its being covered over. I think, too, that the sculpture of various sorts which can be seen on so many common seeds, such as those of the Stitchwort, the Ragged Robin, the Cut-leaved Cranesbill (Fig. 52, see Plate V., p. 144), and the Ivy-leaved Toadflax, serves the same purpose among others. It is not by any means easy to wet such seeds, for water does not readily soak in between the spines of those of the Stitchwort and the Ragged Robin, or into the pits and depressions of those of the Cranesbill and the Toadflax respectively. Thus they help to keep the seed dry during the dispersal period. When, on the other hand, it comes finally to rest and is kept moist, it is only a matter of time for the water to dissolve the air in the spaces or depressions; and hard as it is to wet a sculptured seed, it is just as difficult when it is once thoroughly soaked to dry it again, except by allowing the water to evaporate. Thus the sculpture probably secures a dry dispersal period as surely as it ministers to the retention of moisture for germination at its close.

As already mentioned, the seeds of some plants become slimy by the secretion of a mucilage when moistened, and when they dry they stick to dead leaves or the soil: the common Plantain is one of them. Those that adhere to the soil secure a certain amount of anchorage, but those that are upon dead leaves have a chance of greater things, for it is a matter of very easy observation that dead leaves are always being dragged underground by worms. Hence the mucilage may secure not only dispersal as already pointed out, but also being sown and anchored in a suitable place The seeds of most plants, however, have so far as I know no special contrivance for adequate burial, but depend upon drift for being covered over. The student should, however, bear this necessity in mind, for it is one of real importance, and it is surprising how much still remains to be found out about plants which every one at all interested in Botany knows well enough by sight and perhaps by name, without, I am sorry to say, knowing much, if anything at all, about their life-history.

The Ivy-leaved Toadflax, for example, is to be seen commonly on old walls in many parts of the country: on one in my own garden it thrives in profusion, and it is one of the few species that has learnt to sow at any rate some of its seeds, in the crannies and crevices of the wall upon which it is growing, although it does not anchor them. It has long flowering shoots, and the fruits are borne upon slender stalks: after the blossom has fallen the stalk curves away from the light and towards the wall, and as it lengthens it pushes the fruit into any hole or cranny that happens to be available. When the latter is quite ripe it opens by pores and the seeds are shed. It is worth notice that the fruit is one of those that only open in dry weather and close up again when wetted. Of course the seeds are not all shed into holes, for they may be and often

Fig. 27.—Fruit of the Ivy-leaved Toadflax. After dehiscence. × 4.

Fig. 28.—Seed of the Ivy-leaved Toadflax. × 25.

are merely dropped on to the top of the wall, and if the long stem be hanging down its side many of them simply fall to the ground at its foot. I have seen them carried off by black ants, but what I want to point out is, not their dispersal modes, but the fact that the plant itself sows some of them in places that are suitable for germination, for the holes and the cracks in a wall are not anything like so dry as one might think; they not only collect but they retain, comparatively speaking, a considerable amount of moisture and grit of one sort and another.

A fruit of this plant commonly contains more than forty seeds, and of course if they all germinated in a cranny where there was room for only one adult the seedlings would be so crowded that all of them could not possibly thrive and attain to maturity. We must, however, remember that the number might be reduced

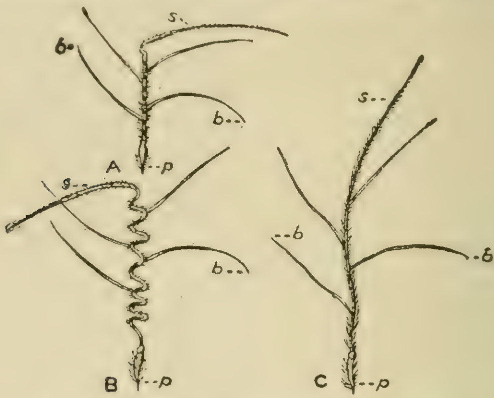


FIG. 29.—Fruitlet of the Storksbill. ×1½.

A, dry and closely coiled. B and C, wet; B partially and C fully uncoiled. The seed is at (*p*). As the spiral uncoils the scythe-like end (*s*) catches in the surrounding herbage and forces the pointed end (*p*) into the soil. Should it dry and coil up again the hairs upon (*p*) prevent that end from being dislodged, but the smooth scythe will slip. The side bristles (*b*) help to maintain the upright position as the fruitlet slips through the herbage to the ground.

by ants and other means, and, even if it were not, the struggle for existence among so many seedlings, where only one could survive, would be so fierce as to ensure the best one winning, and this, as we know already, is one of the objects that Nature never loses sight of: she always likes the best man to win.

So much, then for the Ivy-leaved Toad-flax; but there are just a few plants in our own Flora that go one better, for provision is made for anchorage as well, and the Storksbill, a near relative of the wild Geraniums or Cranesbills, is an example that lends itself to comparatively easy observation. I recommend the reader to collect some of the fruitlets and to drop them dry into some wet herbage in order to witness the performance. The mechanism has been described in a good many books, and with the help of the illustration and experiment he will readily understand the use of the long side bristles, the sharp point, and the stiff hairs which give the seed-end the appearance of a miniature brush.

FIG. 30.—Seed of the Garden Scabious. × 3.

It is clear, then, that the Storksbill anchors its seeds before germination commences, and that seems to be the common-sense procedure; nevertheless, with very little trouble we can observe a remarkably neat contrivance by which anchorage is effected by the seedling itself in the process of germination.

FIG. 31.—Seed of the Garden Scabious germinating. × 4.

In our own Flora we have the Small Scabious, but another species which is commonly grown in our gardens, where it is sometimes known as Pincushions, is more convenient for our purpose because the seeds are so much bigger.

It is as well to pick out three or four of the largest and to place them on a potful of damp light soil during the warm summer months; there is no need to bury them or even to press them in. We should put a sheet of glass over the top of the pot for a couple of days so as to keep them thoroughly moist. If, at the end of that time, we remove one of them and hold it up to the light we shall see near the top thin areas or occasionally holes between the ribs. We must then replace it, and we should keep daily watch for a short time; within a week, if the seeds are sound, we shall find that germination has commenced. The radicle pushes out of the top of the seed and at once grows straight downward; it always appears exactly opposite one of the thin places between the ribs and grows right through it into the soil beneath. Thus the seed is so firmly anchored that there is never any difficulty about the cotyledons being withdrawn. Within a few days they get completely free and spread apart to set about their business, the husk of the seed remains pinned to the soil where it soon decays, and so it comes about that, given a sufficiently high temperature, soft soil and adequate moisture, the seeds of the Scabious need be neither anchored nor covered over when sown, although the seedling possesses green aerial cotyledons. We must not, however, fall into the mistake of thinking that they dispense with the necessity of anchorage altogether, but instead of depending upon outside help

Fig. 32.—Seedling of the Garden Scabious. Natural size.

the seedling itself provides for its own security in this all-important respect by making it impossible for the seed-coat to be carried up into the air by the lengthening stem.

The subject of burial and anchorage is one that is full of interest, and I have introduced it, not in order to discuss it in detail, but, as throughout these pages, in the hope of stimulating curiosity and inducing the reader to see and find out things for himself. It will most certainly be good for him to do so, and it will, almost as certainly, add something to our scanty knowledge of our own Flora.

It remains for me to point out that although one is apt as a rule to think of pollination, seed-dispersal, burial and anchorage as being done for the plant, yet the vegetable world is not altogether devoid of the virtue of self-help in these matters. Self-pollination is of course familiar alike to floriculturists and botanists; we have had before our notice in the last chapter instances of self-dispersal, and in this one, of self-sowing and self-anchorage; we learnt in the second chapter that the green plant is quite independent of the animal world as regards food, in other words, that it is self-nourishing; so it appears that the dependence of the animal world upon the vegetable is vastly more vital than that of the vegetable upon the animal. Nevertheless, the mutual dependence of the two is so complete that it is far more profitable to realize that fact than to make an attempt at striking the balance.

We have now reviewed the whole life of a plant in very broad outline: the anchorage and germination of the seed bring us to the commencement of the next generation, and all I need say about the latter is that in most cases, although not in all, the radicle is the first to grow out of the seed, and that it is followed by the appearance of the cotyledons or the foliage leaves, as the case may be. We shall do well to sow the seeds of our wild plants for ourselves to see how and when they germinate, for our Nature-study will not be complete, however good it may be in other respects, if it tells us nothing at all about the birth of the seedling. As I have said already, we should sow them as soon as they are ripe and note how long they take to germinate and the changes that take place between infancy and maturity; in many cases they will surprise us not a little, and in all they will provide us with a great deal more pleasure and interest than we wot of.

My readers will, I trust, understand that in setting forth the seven factors of life, animal and vegetable, I have given but a very meagre idea of the various ways in which they are satisfied in the world of plants; there are modes and happenings in endless profusion that I have not even mentioned; I have been more concerned to point out what to look for, what to observe, and how to find out things for themselves, instead of resting content with studying the work of others to the exclusion of doing any of their own. These chapters are, as it were, a theory, or a working plan for the Nature-study of plants in general, and I propose devoting the remainder of this book to putting the theory into practice by applying the plan to a particular plant, the Herb Robert, and then to its nearest relatives, the Cranesbills, as well as to the Storksbill, which belongs to the same family.

Meanwhile we may rest assured that every observation we can make, every fact we can glean, every conclusion we can reason out, will have to do, often in more ways than one, with one or more of the Seven Factors of Life, which may be tabulated conveniently as follows :—

Factors	Concerned with
1. Respiration. 2. Nutrition. 3. Growth. 4. Protection. 5. Rest.	Which are concerned with the Preservation of the Individual.
6. Reproduction. 7. The care of the Children.	Which are concerned with the Preservation of the Race.

We must bear them in mind always in our work, and we must never forget for a single moment that the Scheme of Creation is founded, not upon self-seeking, but upon co-operation.

Whether we study Nature in order to become a professor or merely as a recreation, we must recollect that as students our object is to become acquainted with the ways of Nature, to find out what our organism does, why it does it, and how. We must, whenever it is possible, see and do, or at any rate try to do, things for ourselves; we must stick resolutely to one job at a time; we must not be led away by side issues; and finally we must never undertake more than we can reasonably expect to be able to do properly.

PART II. PRACTICE

CHAPTER VII

THE LIFE-HISTORY OF THE HERB ROBERT (*Geranium Robertianum*, Linn.): ITS ROOTS AND LEAVES

THE Herb Robert has the great merit, so far as our present purposes are concerned, of being a common and well-known plant. In suitable places it can be found all over our country at all times of the year, and except that it avoids marshes and bogs it is not particular as to habitat, for it seems to be at home on shingle, old walls, dry sunny banks, and more or less shady hedgerows. In one part of my own garden where it gets little or no sunshine for the greater part of the year it would, if I left it alone, be a troublesome weed, and in another it grows flowers and ripens its seeds on a wall that faces south and comes in for a considerable amount of sunshine all the year round: in a position of this sort, however, the plant can hardly be said to luxuriate

In addition to Herb Robert it is known as Herb Robin, the Stinking Cranesbill, and more shortly as Stinking Robert. It has other English names too, for example, Knife and Fork, while scientifically the correct one is *Geranium Robertianum*, Linn. I should like to say a little about its names because, even when we are occupied with dry Science, we must never be dry old sticks ourselves: we must remember that names are full of romance and meaning, and intelligent Nature-students should not, indeed they cannot if they have any healthy imagination at all, confine their different interests in separate compartments which are watertight and mutually exclusive.

There is profound truth in Shelley's lines :

> "Nothing in the world is single ;
> All things by a law divine
> In one another's being mingle,"

and the names of a plant belong in a very winsome way to its life-history, for are they not the reflex of some of the impressions made by their owner upon the human race ?

It adds immensely to the value and the beauty of the mental picture we form of the life of our common and well-known plants if we understand a little about the origin of their popular names : the scientific ones too are not infrequently, although by no means always, singularly apt and well chosen.

We cannot quarrel with the Herb Robert's, since Geranium comes from a Greek word *γέρανος*, a crane, and we shall see presently why it is called Cranesbill. The meaning of the Robert or Robin is not quite so clear : its connection with this plant is some six to seven hundred years old. It may be simply a corruption of Rob-wort the Red plant, or it may have to do with an ancient saint or perhaps with a physician of that name who used it in his practice, or else with a disease from which a famous sinner Duke Robert of Normandy is supposed to have suffered and to have been cured by its medicinal properties, more valued in olden times than nowadays.

The bestowal of names, however, is the work of man, and we must confine ourselves to the work of the plant in response to its surroundings, otherwise

I shall be guilty of defying one of my own golden rules, namely, to know exactly what one wants to do and to do that first, resolutely leaving the attractive side issues to be dealt with afterwards, or not at all, as inclination and opportunity may allow.

Now, if we were going to write the life of a man, we should not begin by describing what he was like or what he did in his prime, but we should start with birth and childhood. We should in fact make the narrative continuous from infancy to death, and I have found this much the more satisfactory way of dealing with plants.

Fortunately it is easy to watch our friend from its babyhood to its grave, and I will give its history in outline as clearly as I can.

Although it will grow and flower in almost any situation, it thrives and is at its best when in a damp spot, among more or less dense low-growing herbage where it is sheltered from parching winds, and gets some sunshine which must not be too hot and continuous. It was in a position of this kind that I made almost the whole of these observations, some of which do not hold good for plants that grow in very hot and dry places.

FIG. 33.—Herb Robert seedlings. Half natural size.
A, cotyledons; B, first foliage leaf. (*Photo.*)

In the moist places there is no difficulty about finding seedlings of various ages from mid-July until the following April, that is to say for nine months of the year. Even in mid-winter there are plenty of them, for those seeds which germinate during the summer and early autumn make a few leaves before growth is brought to a standstill by the cold. They retain them all through the winter, so that one can begin one's observation of the youngsters practically at any time during those nine months.

It is wise, however, not to begin during the winter itself, because the thermometer is then so low that it is no use attempting to watch development. There are plenty of different stages to be found, from the first appearance above ground of the two cotyledons to plants with a few foliage leaves, but things are at a standstill.

During the autumn and the spring one can on the contrary note the changes that are taking place, and the autumn is the better season of the two because we shall already have made our observations on the seedlings by the time that spring comes round, and so be all the more free to devote the whole of our available time to the later stages.

FIG. 34.—Herb Robert seedlings, with foliage leaves, and (S) the stumps of the leaf-stalks. Half natural size. (*Photo.*)

One plant that I watched pretty closely had four foliage leaves at the end of the year, and it kept them fresh and green, except for a suggestion of red, all through the winter. By about the end of April an autumn seedling will have a beautiful crown of leaves, its very short stem will have increased in diameter, and the part nearest the ground will be surrounded by the bases of the stalks of those leaves which have done their work and withered away.

Now, just as it is quite impossible to confine one's various interests in life each within its own separate compartment, so it would be a great mistake to try to deal with the closely interwoven factors of life one by one; for the life of a plant is, like its body, one harmonious whole, of which we can form a mental picture only by realising the interdependence of its various organs, their functions and their activities.

We shall frequently find as we progress that one observation persuasively suggests the next until we have formed our outline of the whole, although it would probably take years of labour and research to get within measurable distance of being able to fill in the details.

Having noted the changes in the seedling from autumn to spring, let us take an early opportunity of digging up a plant in March or April, and, confining ourselves in this chapter to the roots and leaves, let us find out, so far as we can, how they do their work.

The reader will doubtless remember that they are concerned especially, although in different ways, with respiration and nutrition, and consequently with growth too, for that depends upon and is the result of adequate nutrition.

In addition to anchoring the plant in the soil, the root takes up water, wherein are dissolved not only oxygen, which is essential for respiration, but also various mineral salts, which are indispensable for food manufacture.

The seedling in the illustration, taken at random from my shady border, is amply provided with well-branched roots: growing as it did in a place where the ground rarely got parched even on the surface, its numerous and finely divided rootlets were just the thing for occupying the moist interstices of the soil and for absorbing the water films surrounding the small particles of which it is composed.

FIG. 35.—Herb Robert seedling to show the root-system. ½ natural size. *(Photo.)*

It is, of course, not the rootlets as we see them with the naked eye that pump water into the plant, but the very much finer and more delicate root-hairs which they bear close to, although not actually on, the extreme tip.

Let us now turn to the leaves: they play an indispensable part by taking from the air in which they grow free oxygen as well as carbon dioxide, which yields further supplies of oxygen in addition to carbon, and both these elements are among the components of starch and other foodstuffs.

I need perhaps hardly add that this by no means exhausts the activities of green leaves in the all-important matters of respiration and nutrition.

And here I should like to say a little about the pores through which the air gains access to the interior of the leaf.

I took some little trouble to estimate how many there are on an ordinary leaf; and I found about ten upon a piece of the skin so small that it would require roughly 8000 of the same size to cover one square inch. I should mention that there are few or none at all upon the upper surface of the leaves of this plant, but at this rate for every square inch of leaf there are on the underside 80,675 pores, and on a well-grown leaf a full half-million or more, according to its size.

Now, it is not easy to realize what 80,000 things of any sort would look like if seen all at once. On a field of five acres 80,000 people would form a dense crowd : a pile of 80,000 halfpennies would be considerably taller than St. Paul's Cathedral, for there would be more than 10,000 of them left over ; a nice little sum, to be exact, of £21 1*s.* 4*d.*, and it would be as much as or more than most of us could do to carry half of it a few yards, for five pounds' worth of halfpence weighs fully thirty pounds.

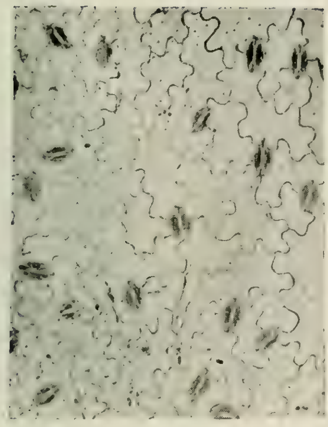
If we arranged the 80,000 coins in a square its sides would measure about eight yards, and if we started on Monday and counted for two hours a day at the rate of 100 a minute, instead of having a holiday on the following Saturday we should have to put in extra time to the extent of one hour twenty-six minutes and three-quarters in order to finish counting the pores on one square inch of leaf before Sunday came. Two hours for five days and three and a half on the sixth, and then we should only have done about one-seventh of a well-grown leaf.

So I think there can be no doubt that those of the Herb Robert are not likely to be suffocated from want of breathing pores.

It may be of interest to turn for a moment to the pipes which, as I have said, run through the whole body of the plant, carrying water and dissolved salts

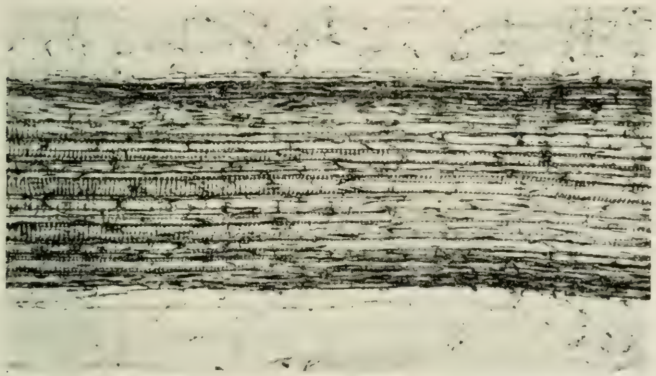
PLATE III.

I.



II.

III.



I. Herb Robert: Pores on the underside of the leaf. The dark ovals with a white line down the middle enclose the pores. × 130. Fig. 36.

II. Herb Robert: leafstalk cut across to show the four bundles containing the water-pipes. × 12. Fig. 37.

III. Herb Robert: one of the bundles in the leafstalk cut downwards to show the water-pipes running lengthways, as at WP. × 100. Fig. 38.

P. 96.]

from the root to the leaves for the purposes of food manufacture. There are four bundles of them in each leaf stalk or "petiole," one being much smaller than the other three; we can see this much for ourselves with a little trouble, if we remember how we manipulated the Iris root, and the illustration shows a section of a petiole that has been divided into two crossways; so that we are again looking as it were into the pipes which have been cut across.

The starch grains that are formed and which help to nourish the plant and to provide what is necessary for its growth and other activities are extremely small, their diameter being not more than $\frac{1}{2500}$ of an inch as a rule, and often very much less: they, however, respond readily to the iodine test, and if we squeeze some of the juice from the petiole on to a glass slide we can in this way easily satisfy ourselves as to their presence there.

Now, if we watch one of the young plants in the open we shall find much to interest us in its growth, although of course we cannot witness that cell division of which I spoke previously; but we shall see this: that for weeks or months it forms nothing but leaves, at any rate above ground—it is in fact growing up.

If we watch a single leaf from the time that the unexpanded blade begins to appear, we shall find that it goes on increasing in size until it has reached its maximum. The largest one that I found measured five inches by four and three-quarters, but this was exceptionally big. Later on the leaf begins to wither and to lose its green colour: it may turn a brownish-yellow or more or less red, and sooner or later it dies and decays. Its stalk withers too, until there is nothing left of it but a thick ruddy stump.

During its life it is busy making food, which is stored up in the stem and the stump against the time when it will be required to nourish the flowers and the seeds which will be produced later on.

The last thing that happens before its dissolution is that all the food that it still contains passes out of it and into those parts, including the stump, that are not going to die yet awhile (see Fig. 34): the plant must not and does not waste the precious stores that have been formed in its life-substance by the green leaves and the light of the sun.

It has been suggested that when the Herb Robert grows on the side of a wall, as it sometimes does, these stumps help to support it and to relieve the strain upon the roots caused by the weight of the plant. I dare say the lower ones act in this way, and indeed I have no doubt that they must do so whenever they happen to catch in a crevice or a small hole, but since they are found regularly and in equal abundance upon plants growing upon flat ground where no such support could be of any use, we must not think of them as being produced for this reason: their true function is to act as a food reservoir, or as we should say in our own case as a larder or a store cupboard.

I must now draw attention to a point of interest in the blade of the leaf. It is cut up into somewhat small areas, and this feature of leaf areas of small extent is commonly found in plants that are annuals and grow under conditions similar to those of the Herb Robert.

A large low-growing undivided leaf would be likely to have a considerable portion of its surface shaded or overgrown by the surrounding herbage, involving a considerable amount of waste of material, hence we frequently find that if the leaves of the plants of our hedgerows are large they are more or less cut up into small areas, while small leaves, like those of the Chickweed, are not divided. We can then well believe that our plant need fear neither suffocation nor starvation, and that, other things being equal, it can have no excuse for failing to grow into a thing of beauty. A healthy plant in congenial surroundings will make quite as many as 80 leaves before it begins to flower; they will not all be in evidence at once, for as the later ones appear their predecessors wither away. I have counted 62 on a single plant, all fresh and vigorous, just when the flowering stems were beginning to sprout.

FIG. 39.—Leaf of (*a*) Herb Robert, and (*b*) Chickweed. ½ natural size. (*Photo.*)

That was in my own garden, where I like always to have at least one plant. As a rule I discourage the others quite successfully with the Dutch hoe, but one year I left them alone on purpose to make these observations, and I should be afraid to say how many I had: they certainly numbered some hundreds, and they were all the children of one parent.

Now, I sometimes read about gardening as a peaceful and delightful recreation, as a gentle and a civilizing art in the practice of which one forgets that there are such things as bad words.

Personally I find that, apart from the grave perils of the elements, such as drought, deluge and whirlwind, it consists very largely in an everlasting but more or less vain attempt to save here and there a plant that is not a weed from the ravages of the ferocious and strenuous warfare which is waged day and night, and especially the latter, by an innumerable host of sleepless, relentless and hungry foes. They devour one's treasures and show no respect either for infancy or old age. Grubs of all sorts and sizes, snails and slugs, green fly and blackfly, earwigs and millipedes, rust, smut and mildew, are some of the worst of the enemies that the gardener has to fight, against fearful odds, from New Year's Day to New Year's Eve in pursuit of this restful and soothing hobby. Nevertheless, one must remember that in a garden plants are placed under highly artificial conditions, and we must never think that the children of God's creation, either animal or vegetable, live naturally in an everlasting and universal state of internecine warfare : on the contrary it is, as I have already pointed out, much nearer the truth to think of nature as a gigantic co-operative society, the oldest and most successful that one can imagine ; but that is a matter on which I need not expatiate any more.

Now, I have been engaged in the amiable pastime of unsuccessful gardening for some years, and I was naturally struck by the fact that the Herb Robert in my borders, which are a well-stocked menagerie of small and voracious wild beasts, seems hardly ever to be attacked and this of course set me thinking about its protection.

The first thing that I noticed was that it is supplied liberally with long hairs, and then I remembered its smell, which is emphasized in some of its popular names.

The hairs clothe the stem and leaves as well as the sepals, and, like some of those that are to be found upon many well-known plants, they are glandular :

to the touch, they are slightly but not very noticeably sticky. They occur in countless numbers all over the plant, and so thickly on the young leaves that they mask their real colour in certain lights, and glitter like the hoar frost in the sun.

As the leaf increases in size they naturally become more widely separated, but are still quite plainly visible

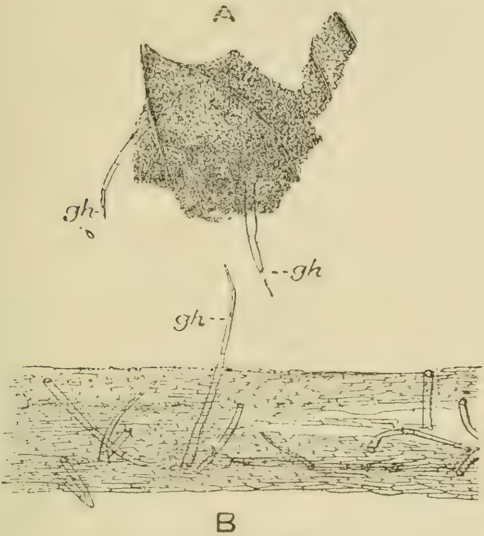


FIG. 40.—Herb Robert.

gh., glandular hairs on (A) leaf. × 15. (*Photo.*)
(B) stem. × 15. (*Photo.*)

to the naked eye. The majority of them are long enough to be both seen and felt, but there are others which can be observed only with the help of a good lens or a microscope: they too are glandular, but quite short and stumpy, although the gland itself is much larger.

Now, the known uses of vegetable hairs are manifold, and although it seems pretty certain that these make the leaves unpalatable to the bulk of animal life, I could not speak decisively without a great deal more evidence than I possess.

Fig. 41.—Herb Robert. Glandular hair from the leafstalk to show the gland at *g*. × 120.

I have two kinds of snail * in my garden in such unconquerable abundance that I can always supply any one with a very liberal allowance of either at short notice. I collected a few of each sort, putting them into separate jars covered with a sheet of glass, and giving them some of the leaves of the Herb Robert for food: but they would not touch them, and although I kept the supply fresh they ate nothing at all for a whole week.

Again, I have four kinds of slug, and their doings were decidedly peculiar.

There is a small black one † that steadily refused to eat the leaves. Then there is the Milk Slug, ‡ which after four days did have a nibble and seemed to be none the worse for it. Thirdly, there is a large brown one; § he began eating during the second night, but by the next evening he had turned a fearful colour and was dead.

* *Helix aspersa* and *Helix rufescens*.
† *Arion hortensis*.
‡ *Limax agrestis*.
§ *Limax maximus*.

Lastly, there is the Great Yellow Slug,* that does not as a rule care about fresh food, but prefers high game, so I was not surprised at finding that he left his rations alone, until I supplied him with some leaves that were decaying, and this of course would not be harmful to the plant.

It should be borne in mind by any one who makes experiments with slugs in captivity that, being devoid of the protective shell into which the snail retires, they must be kept moist, otherwise they will dry up and die even when supplied with suitable food, with the result that one may be misled into attributing death to poisoning instead of to drought.

Again, I have far too many woodlice; I did not expect them to eat the leaves, for they like succulent fruits and petals as well as the same sort of nasty food as the Yellow Slug, but I was not prepared to find them all dead the next morning.

Indeed, I was so surprised that I put a few into a moist box without food and a few more into one with some of the leaves, with the result that the former lived for three days, when I released them, whereas the latter died the same night: so it is possible that the leaves give off fumes that are fatal to these creatures.

I may add that I took similar precautions with a view to eliminating possible sources of error in my other experiments, and that it is imperative always to do so, however troublesome it may be.

I turned next to the caterpillars. One night I saw one of a Yellow-underwing on a leaf which was not quite whole. I did not catch it in the act of nibbling, and I meant to secure it in order to find out the truth: unfortunately I dropped it and could not find

* *Limax flavus.*

it again in the dark, and although I looked for it in the daylight on several occasions afterwards I never saw it again. Later on I fed a larva of the Small Yellow-underwing * for six days on the leaves of the Herb Robert and nothing else : at the end of that time it burrowed in the soil, and subsequently it pupated and hatched out quite normally : but I do not think it would have eaten these leaves from choice had I given it, for example, some of those of a Dock or a Primrose as well.

Then there is the caterpillar of the Tiger Moth,† known as the Woolly-bear, a very omnivorous creature, to whom little indeed seems to come amiss.

I kept one of them in captivity and supplied it with leaves ; it ate a very little two nights running, and then looked very unwell. It is often quite easy to know when a caterpillar is not up to the mark ; it behaves differently, and this one lost the beautiful bright gloss of the long shaggy hairs that give it its popular name.

I rather wondered what was the matter, especially as it got very restless, for it did not seem to me to be about to moult or to be full grown, so I gave it other food ; nevertheless, after starving for another four days it spun its cocoon and turned into a chrysalis.

I thought then that all was well, but I am sorry to say I have still got the chrysalis, for the moth which it contains never succeeded in forcing its way out as it ought to have done.

I wondered without forming an opinion whether the diet of Herb Robert for two days had anything to do with its untimely death, and a second experiment leaves me in much the same state of mind, although

* *Triphæna orbona.* † *Arctia caja.*

the two together certainly suggest that it is not wholesome food for this caterpillar, but perhaps my first friend was out of health when I caught him. The other was a much younger and apparently a perfectly healthy individual. I gave him various leaves of other sorts for a few days, and then nothing but Herb Robert. He began upon it at once, and ate, as is the custom of caterpillars, a large amount daily for five weeks and two days. I gave him a few dead leaves among which to spin his cocoon, but to my great surprise he made not the least attempt to do so; he simply lay still and turned into a chrysalis without more ado, on the soil in the pot with which I had provided him. This chrysalis was evidently healthier than the other, for the moth appeared in due course. It was quite typical as regards both colour and pattern, but it was considerably smaller than usual, the length of the front wing being barely an inch, which is short even for the male, which is normally smaller than the female.

Now, it is rather remarkable that, except for the Milk Slug, the larva of the Small Yellow-underwing and the second of the two Woolly-bears, either the living leaves were not eaten at all or the eaters came to a premature end, while the Woodlice seem to have perished from being shut up with them in the same box, and the Tiger Moth was undersized. All the same one must not attach too much weight to a few isolated experiments of this sort, and I do not feel inclined to say more than this: that they suggest that the leaves are protected from marauders by their secretions and glandular hairs and perhaps by their exhalations too. I am told that in some parts of the country the cottagers like the plant because they believe it keeps off insect pests, such as flies, and it is quite possible that they are right. I cannot pretend to know anything worth mentioning about organic chemistry, but the Herb Robert produces a good deal of tannin and its near relative gallic acid, and I think that these are hardly likely to be a very desirable addition to one's diet.

I remarked in Chapter III. that probably all plants have their dependant or dependants who look to them for some if not for the whole of their sustenance. What I have written I have written, but I confess I have found an extraordinary difficulty in justifying that remark so far as the Herb Robert is concerned.

Since my last trial with the Milk Slug I have occasionally seen it nibbling the leaves at night, the caterpillars of the Tiger Moth and the Small Yellow-underwing and some others are no doubt occasional hangers-on, there is a small brad-shaped yellow grub, probably of a fly, that I have found eating the immature seeds, and I once, but only once, saw some cuckoo-spit on a plant, for it was not there the next day.

There are, however, two other well-known evils from which plants suffer: one of them is the galls of one sort or another that are more conspicuous on the leaves of our trees than on our herbaceous plants.

Our Oaks and Beeches are often attacked by them, and the small flies that are hatched from them tempt me to say something about their natural history, but once again we must steer clear of the side issues. Galls, however, are to be found upon our herbaceous plants as well as upon the leaves of trees.

The Speedwells, the Nettles, and the Wood-sage are very commonly attacked, but these are only a few of the lowly herbs upon which they can be found by any one who cares to look for them.

The other evil is the small Fungi to which I referred as Rust, Smut and Mildew, and which do an incalculable amount of harm to wild plants and cultivated crops. In the earlier months of the year the leaves of the Wood Anemone, the Stinging Nettle, the Goatsbeard, Cleavers and many other wildlings are frequently spotted profusely with these unwelcome parasites.

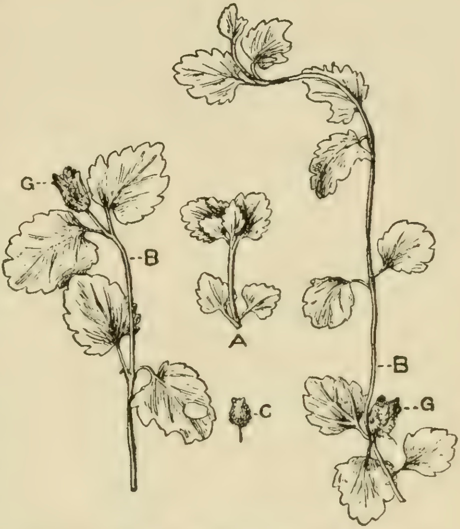


FIG. 42.—Galls on Speedwell. ½ natural size.
A, normal shoot; B, shoots with gall G; C, gall with aborted leaves removed. (*Photo.*)

Such spots upon those of the Common Barberry, for example, are pretty enough when seen under the microscope or a lens, and they are often called Cluster-cups, the reason of which is obvious when we have them magnified sufficiently.

Now, I have never seen either galls or Fungi on the Herb Robert, and as far as the British Isles are concerned I believe that no one else has either; if therefore any of my readers should ever come across evidence of either of them I hope they will record the discovery, which would interest a great many people in addition to the author, especially as both pests are known to prey upon other kinds of Cranesbill and, on the Continent, on the Herb Robert too.

FIG. 43B.—A single Cluster-cup from the leaf of the Stinging Nettle. × 7.

It seems then certain that our plant suffers but little from the ills to which vegetable flesh is heir. Slugs and snails eat the pretty pink petals after they have fallen, and the Great Yellow Slug devours the decaying leaves; but of course neither of these operations can do any harm, on the contrary they help the hungry and illustrate the co-operative nature of the Scheme of Creation to which I refer so frequently.

I began to think that the Herb Robert had to all intents and purposes solved the problem of complete protection, but after all it has at any rate one dependent. There is the grub of a beetle, a weevil, known as Cœliodes that habitually feeds upon it. It is not by any means common in England, and it is one of those small maggots that are seldom seen because it lives and feeds inside the plant instead of attacking it from the outside; it is much more easy to get hold of the beetle itself, which can

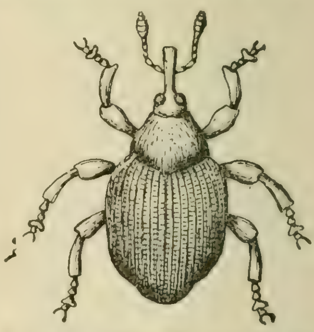
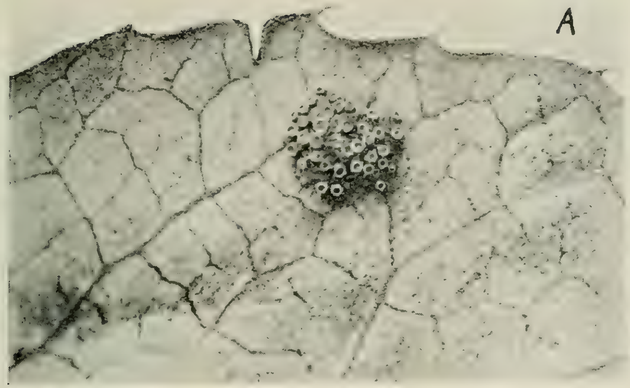


FIG. 44.—The Weevil Beetle (*Cœliodes*), whose Larva is an Internal Feeder on *Geranium Robertianum*. × 9.

PLATE IV.

I.



II.

I. Cluster-cups on the leaf of the Common Barberry. × 5. Fig. 43.

II. *Thrips cerealium.* The prong marked O is the ovipositor, which was displaced upwards in mounting the specimen for the microscope. × 25. Fig. 47.

P. 108.]

be swept in plenty from the plant in the places where it is to be found at all. Nevertheless we must admit that our friend has managed to protect itself with remarkable success.

There is another danger, however, with which all living things have to reckon, and it is that of being crowded out in the struggle for existence.

The mutual competition between the plants growing at the foot of an English hedge is so terrible that, if one did not know better, one would shudder to think of the host of seedlings that die off in early infancy.

The Herb Robert is no exception to the rule: its defensive weapon is its spreading crown of leaves, which darkens the space that it covers and so prevents the seedlings of other plants establishing themselves there; but this does not obviate the danger of being swamped by larger rampant and quickly growing competitors hard by. On one small spot in my garden where early in the year I counted twenty-three seedlings there was only one plant by mid-October: all the rest had died, not because they had been eaten, but because they had been overshadowed by their neighbours and had perished from want of room. It is very much a matter of the time that germination commences; if a seed starts in the autumn and makes its three or four leaves before the cold sets in the chances of survival are good. The early spring seedlings do not grow rapidly, and those which start at that season, have but a poor prospect, whereas those which come last of all in March or April or later are almost certain to be crowded out.

This reminds me of a small point of some interest: the Herb Robert is described in our Floras as an annual or a biennial. In my own observation the seedlings that appear in the autumn or winter will have flowered and seeded and died before the winter comes round again, and so they are true annuals. But the late seedlings do not flower at all during their first summer, or before the close of that year. Like the Foxglove, they only make leaves, they pass through the winter in that stage, and they begin to blossom in favourable seasons at the end of April, about the time when the St. Robert to whom I referred has his annual day on April 29th. It is therefore correct to describe these individuals as biennial: it is again merely a question of the time at which the seed germinates.

I have dwelt somewhat at length upon the roots and leaves, because these are the parts about which one finds least, in at any rate most books, whereas a great deal has been written about flowers and seeds; but the reader will perhaps expect me to say something anent Rest and Sleep before I bring this chapter to a close: there is, however, extremely little to relate. There is of course, the winter's rest or quiescence, but the plant keeps its leaves all through; it is in fact an evergreen, and I am pretty sure that whenever it is warm and light enough the great business of food manufacture is resumed. It is not like a tree, which loses all its leaves in the autumn and simply cannot go on because the factory, that is to say the green leaves, are no more.

Again, there is the nightly rest when food manufacture comes to a standstill, not because it may or may not be too cold, but because it is dark: but, as I pointed out before, this Rest is only partial, since a good deal that cannot be seen goes on inside the plant day and night alike; hence all we can say about the Herb Robert's rest, at any rate at the moment, is that the adult plant gets hardly any at all. We shall, however, come across this question again in the next chapter.

CHAPTER VIII

THE LIFE-HISTORY OF THE HERB ROBERT: ITS FLOWERS AND SEEDS

IN the last chapter we were concerned as in Chapters II. and III. with the life and preservation of the individual, and we now come to the flowers, whose duty it is to preserve and perpetuate the race. They, of course, have to be protected from the fury of the elements and dangers of other kinds, and the Herb Robert gives us a very pretty and happy example of one of those happenings in the vegetable world which are often but erroneously spoken of as sleep, and which, as I have said, are in reality protective.

The blossom rarely lasts for more than forty-eight hours. It opens in the early morning, sometimes the petals fall the same evening, but sometimes not until the next day; it is very rarely that they survive the second night.

I think it depends upon the weather; if the day is one of hot sunshine the whole of the business of the petals, which is, of course, to attract pollinating insects, will be done by nightfall, but if on the other hand it is cool and cloudy and the visitors do not come, more time will be required.

Now if we look at a plant in flower we shall see that in the daytime the blossom stands almost straight out, but when night comes its stalk bends so that it hangs downwards. Pretty and suggestive as the position is, the flower nevertheless is not asleep in our sense of the word, but it is protected in this way from cold and damp. It would, for instance, be a disaster for the pollen grains to be bathed in dew: we should observe, too, that the flower is not so widely open as during the day, and the partial closing gives additional protection to the reproductive organs, the stamens and pistil.

Before dealing with them, however, we should note that there is no vegetative propagation in the Herb Robert; its reproduction is effected entirely by seeds.

The flowers are produced on long leafy stems, and the joints upon which both leaves and flower-stalks are inserted are distinctly swollen, a feature that is brought out well in the frontispiece: they contain a good deal of starch. Usually the blossoms are produced in pairs, but very occasionally one comes across three together.

Around the petals, on the outside are five sepals with many long glandular hairs; on the inside are ten stamens, and they surround the pistil in the centre, which is barely visible when the flower first opens.

The pollen grains can be seen quite easily with a lens, but as it is not possible to see as much as one wishes without a microscope, I have illustrated them on a large scale by way of a help.

They are not round like a marble, but they have five slight depressions on the surface and three little excrescences: I may mention, too, that they are yellow, as is very frequently the case, although, as a matter of fact, in some other species of Geranium, as, for example, the Meadow Cranesbill, they are often stained with blue or mauve, which is not by any means a common colour for pollen grains.

Now when one of the grains gets upon the stigma it sends out a tube which grows down into the ovary below *viâ* the interior of the style, and fertilizes one

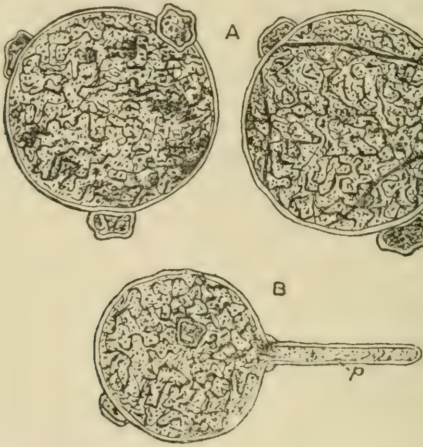


FIG. 45.—Herb Robert. Pollen grains and tube. A × 400. B × 350.

p, the tube.

of the small seedlets right at the bottom of the flower, and it is through one of the three excrescences that the pollen tube starts its growth. How it reaches the stigma, or, in other words, how pollination is effected, is another matter, and we will give our attention to it at once.

What I have written about the protrusion and growth of the pollen tube is not very easily verified by direct observation until one has had some personal experience of inducing pollen grains to start at all, but the reader or student should have no great difficulty in verifying for himself what I have to say about pollination and in adding observations of his own.

As the bright petals suggest, the flower is adapted to cross-pollination by insects. The honey is at the base of the stamens inside the calyx, and in order to reach it an insect must have a tongue about a quarter of an inch long.

I have seen it visited by bees of various sorts which have four wings, and by some good-sized flies which have only two, but it also secures the services of such long-tongued insects as butterflies, among others the Garden Whites: they are, however, decidedly large for a blossom of this size, and the much smaller Blues, which are fortunately so common in our country, are more suitable in this respect.

In my own garden that remarkably pretty butterfly, the Holly Blue, can be seen at work upon it in the spring and more rarely in the late summer, but these are only a few from a long list of visitors that every one who watches can see from time to time during the flowering period, although most of us, including the author, would be at a loss to give the correct name to each.

Now let us look at the arrangements for cross-pollination in the flower itself.

The ten stamens are in two rows of five each, but for the sake of clearness I have only shown five in the illustration, three belonging to one row and two to the other.

When the flower opens the stigmas are not mature, that is to say, they are not ready to be pollinated: we will suppose that it is quite early on a fine warm sunny summer morning, we shall find five of the stamens ripe and close around but slightly above the unopened stigmas, which, however, soon push through and surmount them; that is the first stage. A few hours later the stigmas will begin to open, and the anthers or heads of the ripe stamens will begin to drop off, as they bend away from the centre of the flower; that is the second stage. Still later the anthers of the other five stamens, which up till now have remained more or less hidden, will move towards the centre and shed their grains; that is the third stage. Lastly, they too will drop their anthers and there will be only the sepals and the headless stamens or filaments surrounding the pistil in the centre of the blossom.

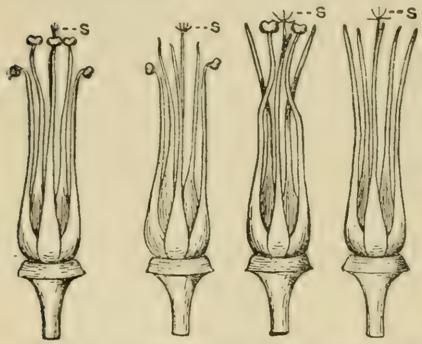


Fig. 46.—Herb Robert. Diagram of four pollination stages (magnified, and only 5 out of the 10 stamens shown). × 5.

Now we should notice that all the time that the stamens have been shedding their sticky grains, the stigmas have either been closed or else expanded above them, and as pollen, like other things, does not fall upwards, all the plans are in favour of a cross.

As a matter of fact, the grains are much too oily and sticky to fall at all, even when the blossom hangs down at night; but, as pointed out in Chapter IV., there are, at any rate theoretically, other possibilities of self-pollination. It was, however, a long time before I succeeded in getting any positive evidence of its occurrence. During June and July, 1916, I protected some flowers from visitors, and I examined their stigmas for pollen without finding any. I saw them wither, shrivel and drop off, and I began to think that self-pollination did not take place spontaneously, or, in other words, that there was no mechanism in the flower itself for bringing it about without the help of an outside agent; but "never" is one of those dangerous words that the Nature-student should hardly ever use. The next year I repeated these experiments, but later on in the season, and it was not until after the middle of August that I noticed for the first time in one of my protected flowers that two of the stamens, instead of shedding their anthers, had moved towards the centre and placed them and some of their grains on to the stigmas. Later on in the same month I found several flowers in my garden which had not been protected, in the same condition.

Pollination is, however, one thing and fertilisation another, and although the latter usually takes place after the former, it does not do so invariably. Out of five protected self-pollinated flowers that I observed closely only two set any seed; in the other three pollination was apparently not followed by fertilisation, for instead of the ovaries swelling the flowers withered and dropped off. On the other hand, the seed from the two ripe fruits appeared to be quite normal, and I obtained seedlings from them during the autumn of 1917.

These observations are, of course, upon a scale far too small to be of much value, but it is at any rate clear that self-pollination must not be ruled out altogether from the life-history of the Herb Robert. Incidentally they teach us that we must not infer from what does or does not take place in June and July what will happen at a later stage, but that we must go on experimenting patiently until we have exhausted every possibility. Since self-pollination as a rule does not take place until the life of the flower is nearly at an end, it is perhaps possible that in some species it is withheld until the plant itself is nearing old age, and, as already pointed out, the Herb Robert does not long survive its one and only flowering period from April to October.

However much or little self-pollination there may be, however, the arrangements, as a whole, leave little to be desired, for the plant sets an abundance of seed.

After the pollination of the stigma the sepals part company to a small extent and the petals fall, whole and unwithered, and then the sepals close up again and help to protect the maturing ovary : the stamens, or rather their antherless filaments, do not fall, but they also enwrap the ovary and, like the calyx, keep pace with its increasing size.

Before I leave the flower I must point out the three light lines upon the petals ; they form, as it were, the prongs of a white long-handled fork, and they are supposed to guide the insect visitor in the right way to the honey at the bottom of the calyx, but that is a very difficult supposition to prove, although I am by no means concerned to dispute it.

I may mention, too, that the blossom is so compact and its entrance so narrow, that raindrops cannot enter and spoil the pollen or the honey, while it is only a very small insect that could possibly creep into it and steal, without paying for its food by effecting pollination.

There is, however, a tiny little garden pest, like a snippet of black thread about one-twelfth of an inch in length, whose name is Thrips, and I have found it inside the flower, apparently chewing away at the pollen grains. (See Fig. 47, Plate IV., p. 108.)

It is really a very pretty little thing, with four beautiful wings and marvellous feet, although we must not allow them to run away with us now.

We should notice, as a guard against unwelcome intruders, the glandular hairs upon the calyx. I have not the smallest doubt that they are protective and prevent small creeping beasts from reaching the flower and nibbling at its vital organs or its pollen grains, without doing any service to the plant by way of payment for its meal. I have frequently seen tiny creatures sticking to these hairs, which of course are no protection against a flying Thrips that is wise enough to alight in the centre of the blossom instead of on the death-trap underneath.

We must now pass on to the story of the seeds. The illustration shows us a ripe and an unripe fruit, and it also gives us the not very obvious origin of one of the names of the plant, "Knife and Fork," from flower and fruit being borne in a pair. On the other hand, the appropriateness of the name Cranesbill is quite clear. It is worth a passing mention that for most of its length the bill is without the long protective hairs, and despite the presence of a few very small glandular ones, too short to act as a deterrent, it is not at all uncommon to find green fly comfortably established there, whereas they are not able to settle down on the other parts. The hairs on the upper part of the bill are not glandular; they seem, nevertheless, to be pretty effective against green fly, owing no doubt to their length.

Until the fruit is ripe the sepals remain close up against the swollen base of the bill, where the seeds

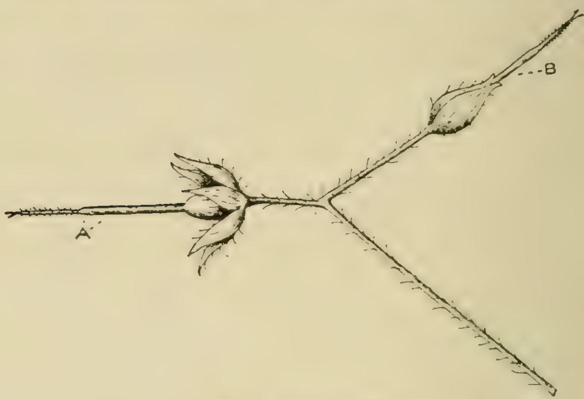


FIG. 48.—Herb Robert (fruit). $\times 1\frac{1}{2}$.

A, ripe; B, unripe.

are to be found, and it is only when the latter are thoroughly mature that the calyx opens.

When this has happened we find that although the petals fell off long ago and the stamens lost their anthers, there are ten long transparent scales between the sepals and the ovary: they are the filaments of the decapitated stamens, now considerably larger than during the pollination period, which have formed an inner protective wrap around the ripening seeds for the last three weeks, for that is the period that elapses between pollination and maturity.

There are five seeds to each flower; one plant that I watched at home, and by no means a fine one, produced its 200th blossom on August 7; during the following week I counted twenty-three more, and it went on at the rate of about two a day until the middle of September.

In some few cases the seeds were eaten before they were ripe by the small yellow grub already mentioned, but my plant must have managed a family of quite fifteen hundred between the end of April and the beginning of October, that is in five months, and, compared with others which grew in more favourable places, this was a small one, for I had it in a pot on a window-ledge where it was not well off for root-room or moisture in the soil.

We have just seen how the Herb Robert protects and takes care of its unborn children until the fruit is ripe, and now we must find out what it does to give them a good start in life, how it provides for the earliest growing days of the little plant inside the seed, and how it arranges for the seeds to be dropped far and wide so as to give them a chance of finding a suitable spot upon which to germinate.

It frequently happens in the vegetable world that the seed contains not only the plantlet, but also a considerable store of food upon which the seedling can draw while it is making its roots and foliage. With the Cranesbills, however, things are arranged differently: there is very little reserve, but the cotyledons are large and they very quickly set about making food; moreover, they last a long time and increase in size as they grow older.

But the question of greater interest is, how do the seeds get dispersed? We know already that land plants rely very largely in this matter upon the animal world and the wind, with a little occasional help from rain-runnels, especially on sloping ground, but the Herb Robert starts in a totally different way; it seems to have a wholesome belief in muscular Christianity, for it begins with what one might almost call kicking its youngsters out of house and home.

To see exactly what happens requires a little patience, but if we choose a sunny morning and select a fruit with its sepals spread out we probably shall not have to wait long, especially if the sun be upon it.

At first there is a distinct suggestion of moisture which very soon disappears, and if we look carefully we shall see that the little swollen knobs at the base, containing one seed apiece, are distinctly hairy. These hairs, unlike those upon most parts of the plant, are not glandular. I think they merely help to keep the precious seed cosy and warm while it is maturing, and after it is ripe they soon dry up and fall or get knocked off.

Now, while we have been noticing these things, changes have been going on in the fruit under our very eyes which probably will have escaped our attention, and presently we shall be startled by hearing a little click, followed by the sudden and total disappearance of one of the knobs which I will call the seeds, although as a matter of fact the seed itself is inside.

Whether this has happened or not at the moment it very soon will, and this is how it comes about.

The illustration shows us the fruit cut lengthways, all the seeds have disappeared except one, and that is on the point of following its four brothers.

As the fruit dries the bill gradually loosens into five strips of elastic tissue arranged around a central rod; by the time that everything is quite ready the seeds become detached from the centre, but they still stand in their original position, each in a little pocket into which it fits neatly, and one rather wonders why they do not fall out or topple over sideways. However, if we have good eyes or a lens we shall be able to see that despite appearances each seed, instead of being free from its elastic strip, or spring, is still attached to it by two threads, and it is a hundred chances to one that while we are looking at it the spring will suddenly curl up with a click and break clean away from the bill.

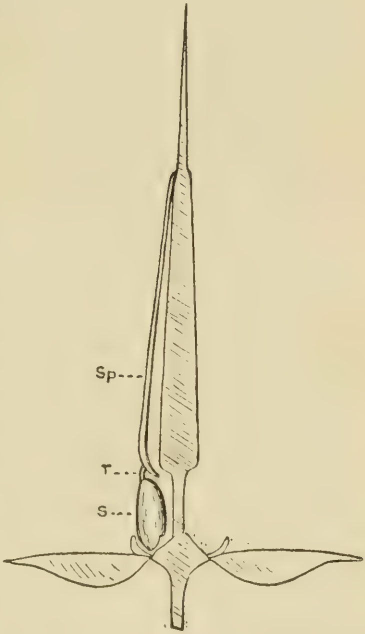


FIG. 49.—Herb Robert. Diagram of fruit about to throw the last of its five "seeds." × 4.

S, the "seed"; T, the two threads; Sp, the spring.

It does this with great force for so small a thing, with the result that the seed at the bottom is shot clear of the calyx and indeed out of sight. The spring breaks away from below upwards, and the threads by which the seed is attached to it are not broken as we might expect them to be; they run the whole way up the spring, and as the seed is shot they are ripped off from the bottom to the top. The whole fruit breaks up thus into no less than eleven separate pieces, as follows: five seeds, five springs, and the central rod which remains in its place.

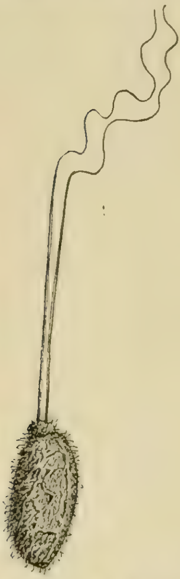


Fig. 50.—Herb Robert "seed" with threads. Strictly speaking, it is a fruitlet containing a single seed. ×6.

Now it is almost impossible to find the seeds after this event, however closely we may watch, for they are tiny things of very much the same colour as the soil, and, moreover, they are shot a distance of about seven yards.

Of course we must see them for ourselves, but if we want to be quite sure that we have got hold of the real thing we must take a few of the just-ripe fruits and shut them up in a box. It is quite easy to tell whether they are ripe or not by the sepals, which open as soon as the seeds are ready to be shot.

We are not likely to have to wait long, and we shall then find that they are little brown, hairy, wrinkled things with two long threads which fine away at the end furthest from the seed to a wisp of gossamer so delicate that it floats in the air and can hardly be seen. Like the fruitlets of the Storksbill, they are apparently hygroscopic for the greater part of their length, by which I mean that they readily take up and part with water in a moist atmosphere, and they curl and wave about in the air in response to changes in its humidity.

We should notice that the body of the seed apart from the threads bears a certain resemblance to a small insect, either dead or asleep, and this may be of some importance in deciding its ultimate fate.

I puzzled for some time over the threads and what their meaning might be, although the suggestion was obvious enough in a broad way: they are so strong that we can take the seed up by them and shake it vigorously without breaking them, and I am quite sure that it is by them that the seeds cling to all sorts of things and so get carried about and dispersed.

If a Field Mouse or a Shrew should run over one of them, all the chances are in favour of their catching in the fur and of the seed being carried on its journey by the creature, who of course would not be conscious of what he was doing.

But feathered as well as furry animals are to be found in our hedgerows, and the Tree Creeper is one of the prettiest. He feeds upon small insects, and may be seen creeping up a tree from the base to the top, looking for food: then he flies to the ground and makes his way through the herbage to another tree, and goes through the same performance again and again. If he comes across one of the seeds he may very well mistake it for an insect, and on realizing that it is nothing of the sort and dropping it, it is quite likely that the threads will come into play; and this, of course, is also possible if he passes over it without noticing it at all.

Another promising bird is the Jenny Wren, which as it hunts about the hedges and shrubberies is as much like a mouse as a bird in its movements. The staple food of both these birds is insects, but supposing a seed-eating bird like a Sparrow comes across one of the Herb Roberts, he will perhaps mistake it for an insect and leave it alone altogether instead of eating it as he might do if he thought it was a seed.

Thus the likeness to an insect, especially in combination with the threads, may be of more or less use and protection according to the taste of the creature that comes across it, for the insectivorous ones may carry off the seed only to drop it again on finding out the mistake, after perhaps a struggle with the threads, while those that do not like insects will not make any attempt to eat it, although the threads may still secure its being carried off unconsciously.

One cannot, however, tell what birds think, and one has to be very patient indeed in order to find out what they do; speculation and supposition are, or at any rate can be, harmless enough, but like guesses and theories they are valuable to science only in so far as they arouse curiosity and stimulate research, and I am therefore glad to be able to say that there are a few more or less remarkable ways in which I know from my own observation that these threads really are of great use.

I have been interested for some time in the part played by Ants in dispersal, and I once caught a black one * in my garden dragging about a seed of the Herb Robert by the threads, which had got entangled in its tiny legs; on another occasion I watched a large Garden Snail † unconsciously pick up one of them, by the threads sticking to it; as it crawled along the whole thing was worked by its movements on to its body. At first it did not seem to mind at all, but after about ten minutes the seed got to a more sensitive spot, and the snail began to sway its body slowly

* *Donisthorpea nigra.* † *Helix aspersa.*

from side to side with that deliberation and dignity which characterise the movements of this voracious mollusc.

I prodded it with the blunt end of a pencil to see if it would scrape it off as it retired into its shell, but in it went seed and all. After an interval of another few minutes it came out again; the seed was still there, but high up one side of its body and close to the edge of the shell on its head side.

I know from experiments I have made with much larger seeds than these that when one of them gets on or near the middle line of the body, which is perhaps non-sensitive, the snail will carry it about, apparently quite unconcerned, for a comparatively long time, and these seeds with their long clinging threads must be difficult ones for the creature to dislodge: so while it is probable that they cling to furry and feathery creatures, there can, I think, be no doubt that ants and snails occasionally help them on their travels. A Garden Snail, however, is not one's idea of an active creature, for if it went on crawling without stopping for three weeks on end at its usual pace of about two inches a minute, it would still have eighty yards to do, or another whole day of twenty-four hours before finishing the first mile.

There is one other unexpected way in which dispersal is helped after the first ejection of the seeds from the calyx: I have often seen them caught by the threads in a spider's web. One knows well enough that these are not very durable; they easily get broken in various ways. I constantly walk into them myself and find bits of them sticking to my clothes and face, so the web may very well be the starting-point of a journey on the "ole clo'" of a wandering naturalist, the body of an animal such as a bird, or the wings of the wind, or the autumn gales ; nor must we forget the value of mud and rain-runnels.

On one occasion I found among the dead leaves in my garden two, to each of which a single seed of the Herb Robert was clinging. When dealing with mucilaginous seeds I referred to the value of fallen leaves for dispersal purposes and to the part that they play, in conjunction with worms, in seed-sowing in Nature. I should add, however, that the seeds of this plant are not and do not become adhesive when wetted ; apart from moisture pure and simple their only other means of clinging is by the threads.

These then are some of the more interesting ways in which the seeds of the Herb Robert are dispersed.

There is still one experiment made by me that is perhaps worthy of passing notice ; it has to do, however, not with dispersal, but with another important point, the sowing of the seeds in the soil. Those of this plant must be covered over to give the cotyledons a fair chance of breaking out of the seed-coat, for germination on, instead of in, the soil is fatal.

In the evening, and especially when it is damp, one can usually find plenty of Earthworms lying well out of their burrows ; now if we take one of the seeds by the threads and drop it on to the wet body of a worm we shall probably give him such a fright that he will vanish like a flash, seed and all, into his burrow. At any rate, the seed will stick, and if the worm happens to be less timid than most of his fellows he will, nevertheless, be sure to disappear at once on the slightest touch or in response to a stamp on the ground close to him. And when he re-appears, as he is certain to do after an interval, it is even odds that he will have scraped the seed off either as he went in or else as he came out again, but whether this is really any advantage or not will depend upon the depth at which it is left in the soil. I cannot speak positively, but I do not think the seedling would grow through more than an inch, if as much. As a matter of fact, the seeds are shot during the warm, dry daytime and not in the evening, and while I do not imagine that they are at all likely to land on the body of a worm, it is on the other hand quite possible that, as they lie on the ground, the hygroscopic threads may cause them to cling to it, as they did to the body of the Garden Snail.

And here I must remark, for I said that we should come to this point again, that ever since I began to deal with the dispersal of the seeds we have been engaged with what is most truly the resting period of the Herb Robert. and indeed of all plants. From the time that the seed is ripe until germination commences the little plantlet lies as it were in its own cradle and rests peacefully. That period may last only for a few days, or it may be for months. The only thing to arouse it is to plant the seed in the soil and to keep it moist and warm, and even so it will often remain dormant for a very considerable time.

I am not able to state how long it can lie low and still retain its vital powers, nor yet the length of time that a seed may be on its travels in Nature and still be able to germinate. That sort of information is hard to acquire and might very well involve a great deal of patient and varied experiment; but I can speak quite confidently when I say that if we take a number of ripe fruits from a plant and let them shoot their seeds in a closed box, and then sow them about half an inch deep all in the same pot, and keep the soil moist and in the open air during the summer, we shall find that in some cases germination commences in a fortnight, and that the cotyledons are well above ground and expanded within the first three weeks, that others germinate at irregular intervals until the winter sets in, while the remainder put in a belated appearance in the spring, although they are all the children of the same parent and are all treated, so far at it is humanly possible to do so, in exactly the same way. They will, therefore, to all appearances stand nine months' burial.

The Herb Robert is a plant that goes on flowering and producing seeds in continuous succession for about six months, and this habit, in conjunction with the variation in the period of dormancy, is no doubt all to the advantage of the species, as giving greater opportunities of eluding this, that, or another of the many dangers to which the seedlings are exposed.

Germination and the release of the cotyledons is, of course, followed in the fullness of time by the production of foliage, and, having worked round to the seedling again, we arrive at last at the point from which we started the life-history, and the story of *Geranium Robertianum* will be repeated by Herb Roberts innumerable in our hedges, lanes and other suitable places from the Land's End to John o' Groat's.

CHAPTER IX

THE RELATIVES OF THE HERB ROBERT: ITS VARIETIES AND NEAREST RELATIVES

I WARNED my readers in Chapter VII. that the observations of which I have just completed the résumé were made upon plants which grew in moist and shady places, and that they must not be taken as applying in all cases to those of a different habitat; they must on no account be regarded as even a fairly complete history of the typical plant in such circumstances, but merely as my own observations during less than two years, within the limits of a small garden; and if we mean to understand the life-history of a species as a whole, we shall have to observe it not only in one but in as many different localities and different kinds of habitat as we can.

I referred incidentally to plants growing upon an old wall, which despite appearances is not so dry and inimical to vegetable life as one might imagine, especially when built of brick, which absorbs a very considerable amount of water.

A much drier place than an old wall is, for example, the stretch of shingle which lies on our south coast between Eastbourne and Bexhill, and there the Herb

Robert grows in profusion, but as a variety * which is in many respects unlike the type.

I should like to draw attention to a few very easily observed points of difference, which may, I think, be attributed to the different surroundings.

The plant is very much less luxuriant and prolific, it is smaller both as a whole and in its leaves and flowers; moreover, it is more fleshy, considerably less hairy and brown-red instead of green in most of its parts.

If we examine its various organs we shall find that the root system is quite different, but in appearance rather than in plan. Instead of being slender and much branched there is a thick fleshy main tap-root which grows downwards and does not branch until it reaches the moist layers some inches below the dry surface shingle, and then it does not branch much. The leaves have shorter stalks; in addition to being more fleshy, smaller, and less hairy, they are much more finely divided and with hardly any suggestion of green in those of the rosette The smaller flowers are frequently of a deeper colour, the petals are narrower, and their white lines less pronounced, while the seeds are without the long threads which are so useful to their brothers in the moist hedgerow; they are, however, dispersed in the first instance by the same mechanism. It would be interesting to know exactly the cause and meaning of all these differences, but beyond suggesting that it is probable that the dry maritime habitat is at the bottom of them, I have not much to offer by way of explanation, though I may remark that when, in 1916, I planted some young specimens from the shingle in moist soil covered with

* Var. *purpureum*.

small stones, the first leaves sent up from the crown were very distinctly greener than their predecessors. These plants flowered in 1917, when I sowed some of their seeds, which produced seedlings with cotyledons and foliage leaves whose colour compared with those

FIG. 51.—The Herb Robert. The shingle variety, to show the root leaves, and flowers. Half natural size. (*Photo.*)

on the shingle was a little nearer that of the type, but still very much darker; the petals remained very much the same, while the seeds were exactly like those of the parent and entirely without the threads.

In 1917 I sowed some of these seeds. The seedlings which they produced were the grandchildren of the original plant, and their leaves were distinctly nearer the type than those of their parent, the petals were somewhat larger and of a lighter pink, but the more conservative seeds were still without any threads.

Their children, the third generation grown in moist soil, and the great grandchildren of the 1916 plants from the shingle, have not yet (October, 1918) got beyond the autumn stage of a rosette of leaves.

Although they are nearer the type than their parent and very much nearer than their grandparent and great-grandparent, these seedlings can be readily distinguished by their darker colour and by their more finely divided and less hairy leaves.

The root system of all three generations exhibited a similar progressive reversion to the type, but in a much more marked degree, that of the great-grandchildren being practically the same as in Fig. 35.

Thus we can trace a gradual return to the typical moist hedgerow plant, most pronounced in the root, less so, although quite clear, in the leaves, but not nearly so marked in the petals, while the seeds remained unaltered for two generations.

These observations lend some colour to the suggestion that the marked differences which occur in the extremes may be the result of growing upon the shingle generation after generation.

It would be interesting, although the practical difficulties would be much greater, to make experiments in the opposite direction with a view to obtaining the shingle variety by breeding from the type, but there is no telling beforehand how many generations it would take to produce the desired result, if it could be done at all, though one is inclined to think that, given the necessary conditions, it would only be a matter of time.

It would also be desirable, in view of the occasional self-pollination of the type, to discover whether, as seems possible or even likely, it is resorted to more regularly in the shingle variety, owing to the comparative scarcity of insects. Lastly, there was a rather curious difference in two other points that came under my notice. Firstly, the interval between the pollination and the maturity of the seeds of my 1917 plants was only seventeen days instead of twenty-one; and secondly, the cotyledons from some of the seeds that I sowed in 1917 appeared above ground in eleven days, that is to say, ten days earlier than for the type. These seeds were sown in a large pot of soil covered over with small stones, and I watered them in with a syringe as being the best substitute for driving rain: it occurred to me while doing so that the absence of threads made it easier for them to be washed into the shingle on the seashore by a less violent downpour. Now, it is easy enough, and probably a great deal too easy, to make shrewd guesses, but guessing is not a very profitable way of studying Nature, and although one can understand that the long threads or an abundance of glandular hairs might not be of much use where not only insects but also birds and other animals are comparatively scarce, one must not conclude that the plant suppresses them for this or any other reason: it is just as likely that on the hot dry shingle it could not produce them if it wanted to. But, however that may be, it is good to note the differences even if we must leave their explanation to more experienced observers or perchance to a future generation.

Occasionally the Herb Robert has pure white flowers, and there are two charming and well-marked forms, rather than varieties in the same sense as the shingle variety: the leaves and stems may show either the red- or the brown-green with which we are familiar, or else be of a beautiful bright green without any suggestion of either of the other colours; neither form is by any means common, and both of them are worthy not only of notice but also of study.

It will again add very greatly to the value and interest of the student's work if he will take the opportunity, whenever it offers, of comparing the particular species that he is observing with its near relatives. In England we have a dozen species of Geranium or Cranesbill and three of Erodium or Heronsbill, to say nothing of their varieties and forms, so that anything like a comprehensive comparative study of their natural history would be a very large order indeed. With the exception of the Dusky,* the Wood† and the Round-leaved Cranesbill,‡ most of the Geraniums occur pretty commonly, if not always wild, whatever the correct interpretation of that somewhat difficult word may be, whereas two of the three Erodiums are rare or local. I propose offering a few hints as to how to set about a business of this sort, illustrated by some of my own observations.

Until the reader has had a good deal of experience as a Nature-student he will be wise to ignore the first two factors of life, for observations and experiments, comparative or otherwise, about respiration and nutrition cannot be made in the field, but only in the laboratory.

* *Geranium phæum*, Linn. † *Geranium sylvaticum*, Linn.
‡ *Geranium rotundifolium*, Linn.

A certain amount can be recorded about Growth, but it should be confined strictly to what can be seen with the naked eye, aided and abetted by the pocket lens, until the student has learnt a little about vegetable anatomy, and knows how to prepare his sections and to understand them when using a microscope: he will then find a world of unimagined beauty and interest awaiting exploration. But occupation of this sort is hard work for which some training is essential; it can hardly be called recreation even by the keenest enthusiast, unless he happens to be one of those terribly energetic persons whose idea of a holiday is to work harder than ever, but at something else.

The fifth factor, Rest, is much more promising. There is a great deal to be learnt about the resting period of our wild plants and their seeds.

Some at any rate of the desired knowledge would not be difficult to acquire, given the necessary time and material, and it would be well within the reach of the hobby-rider, although he would soon discover that, as with everything else, there are unexpected difficulties to be overcome and pitfalls to be avoided.

The other three factors, Protection, Reproduction and the Care of the Children afford an absolutely limitless scope, including what is easy, difficult, very difficult and altogether impossible within the capabilities and lifetime of one human being. The Nature-student, whether he lives in the country or at the East-end of London, need never be dull or in the position of having nothing to do so long as he is possessed of a few seeds and flower-pots, some soil, some water and a window-ledge that gets a little sunshine.

But to return to the Cranesbills, with which I will deal first, confining myself strictly to the British species.

Most of them grow in much the same sort of place, and should be looked for in meadows, hedge-rows and on waste ground; they all have a strong family resemblance and a similar life-history.

Five of them are perennial, including the Meadow* and the Dusky Cranesbill, to both of which I shall refer in the sequel; the other seven are annual or biennial, dying after their one and only flowering and fruiting season, and all these latter have small blossoms frequently less than half an inch in diameter, whereas the perennial species with the exception of the Mountain Cranesbill,† produce flowers of larger size, those of the Bloody Cranesbill ‡ being sometimes as much as an inch and a half across.

Again, all of them are more or less hairy, including the Shining Cranesbill § in my own garden, although it is sometimes described as glabrous. As a matter of fact, as a seedling and in the rosette stage the leaves of my plants have plenty of hairs, nor are the flowering shoots altogether devoid of them.

I need not dwell upon the root system, which does not differ from what is usual for annual or biennial and perennial plants respectively.

The shape of the cotyledons, so far as I am acquainted with them, is very uniform, and the same may be said of the foliage leaves, except that those of the Herb Robert are five angled, and not so plainly circular in outline as the others.

Again, all our species seem to be more or less,

* *Geranium pratense*, Linn.
† *Geranium pyrenaicum*, Linn.
‡ *Geranium sanguineum*, Linn.
§ *Geranium lucidum*, Linn.

although not entirely, free from the attacks of grubs, molluscs, fungi, and other pests, but the Meadow and the Cut-leaved * Cranesbill are sometimes spotted with rust and have their leaves eaten by caterpillars, snails, and slugs. I have also seen the Dovesfoot † and the Round-leaved Cranesbill distorted by what was, I think, fungal disease.

At one time or another I have had nearly all the British species and some of their varieties in my garden, but it was quite the exception for any of them to be eaten, at least until the autumn. The dying and the dead leaves are devoured by molluscs, and the almost omnivorous larvæ, such as the caterpillar of the Great Yellow-underwing, resort to the foliage when other food is scarce.

There is no vegetative propagation, reproduction being effected only by seed, although at any rate some of the perennial species can be propagated artificially by division.

The structure of the flower is of course the same throughout the genus, but it goes without saying that there are many differences in the details. There is, too, great uniformity in the pollination modes, cross-pollination being the rule, but the Small Dovesfoot ‡ has only five perfect stamens instead of ten, and it is much more dependent upon self-pollination than its brethren.

The genus is of great interest in this respect. It was in the Wood Cranesbill that insect-pollination was observed, although its full significance was not understood, by Conrad Sprengel in 1787, one hundred and thirty-one years ago; and moreover

* *Geranium dissectum*, Linn. † *Geranium molle*, Linn.
‡ *Geranium pusillum*, Linn.

it provides examples, as we pass from the large to the small flowered species, of arrangements that exclude the possibility of spontaneous self-pollination, of others in which both kinds occur commonly, and of still others in which self-pollination is the rule rather than the exception. Thus the Meadow Cranesbill cannot be self-pollinated except by the merest and most unlikely accident because there is no overlap, or, in other words, the pollen is all shed before the stigmas of the same flower are mature; in the small-flowered species there is a decided overlap and a good deal of self-pollination; while in the Small Dovesfoot the five anthers mature almost at the same time as the stigmas, and self-pollination seems to be the more usual mode. There is a short-lived separation of the sexes, but in this and in some other of the annual species, all of which are small-flowered, it is the stigmas that mature first, whereas in the perennials, including the somewhat small-flowered Mountain Cranesbill, it is the anthers. The annual species are the less stable of the two in this respect.

It is not easy to see or to suggest any advantage in the earlier maturity of either of the organs, unless it be that the laggard has the shorter period of functional activity, and so is less likely to miss an opportunity because its partner is not yet ready. If, for example, it could be proved that in the Bloody Cranesbill the life of the pollen grains is longer than that of the stigmas, whereas in the Small Dovesfoot it is shorter, one might admit an advantage in the earlier maturity of the anthers of the former and the stigmas of the latter, but I have scarcely a particle of evidence in support of this possibility, nor would it be easy to put it to the test without the skill of

Darwin and the patience of Job, especially in those species whose flowers range only from a third to half an inch in diameter, and last, as most of them do, for only a few hours.

But however this may be, it is interesting to note that as we work from the large conspicuous and attractive blossoms to the small and inconspicuous ones that are likely to be overlooked by insects, so the arrangements for crossing are left behind, those of the Meadow and the Dusky Cranesbill, for example, excluding self-pollination as certainly as those of the Small Dovesfoot make provision for it.

I have already mentioned the blue-stained pollen grains of the Meadow Cranesbill, but I cannot pretend to explain them, especially as they are white or yellowish when the anther dehisces; and I referred to them as stained on purpose, because the colour seems to come from the cells of the anther after dehiscence. The Cut-leaved Cranesbill also possesses blue anthers, and its grains show a faint tinge of the same shade. It is, in my opinion, open to question whether this colouring has any significance in the life-history of the species, for I am certainly not one of those who believe that every detail of shape, size and colour, every spot, dot, line and tint, wherever and whenever they occur, must be of some value in the struggle for existence, although I am well aware that differences which seem small to our ignorance may nevertheless be, and often are, of great importance to their possessor.

With regard to the time that elapses between pollination and the maturity of the fruit, in the small-flowered species that I have tested, the Shining and the Round-leaved Cranesbill agree with the Herb Robert in requiring three weeks, almost invariably to the day. The Meadow Cranesbill, however, whose flowers are often more than an inch in diameter, took on the average one week longer for each of the six that I marked at various times for observation. One knows quite certainly when the fruit is ripe, not only by the opening of the calyx, but also by the colour of the knob, which on maturity loses its green and turns brown, but it does not follow that the seed is thrown at once or even soon ; on the contrary, that depends upon the state of the weather, which must be fine and dry. I watched one of the fruits of this species daily for a whole week of rainy weather. The first-instance dispersal differs from that of the Herb Robert and agrees with the Cut-leaved Cranesbill's, which I will describe presently. After the ripening of the seed, the knob when sufficiently dry breaks away from the base of the bill but not from the spring, and moves through an angle of ninety degrees, placing itself at right angles to the bill instead of in the same straight line. I looked at this particular fruit sometimes several times a day, and what I saw was curious. The spring is quite distinctly hygroscopic even a long time after the seed has been shot, and there was something rather pathetic in seeing the knob sticking out ready for the throw, and then, when the rain came down and soused it, moving back again to its old position. It went on doing this throughout the week, and it was not until the eighth day that I found that the seeds had at last been ejected.

In this genus a comparatively large amount of difference is to be found in the seeds and in their first-instance dispersal, although the mechanism is the same throughout.

The Dovesfoot, the Small Dovesfoot and the Shining Cranesbill agree with the Herb Robert in ejecting the seed still enclosed in the knob, but none of the other three has the long hygroscopic threads of *Geranium Robertianum.* In all of them the knob is more or less like an insect, and we should notice that the seed itself has a smooth skin in all four.

Things are, however, quite different with the Cut-leaved, the Round-leaved, the Long-stalked,* the Meadow and some other Cranesbills ; instead of being thrown from the elastic spring, which is torn clean away from the central rod, the knob remains attached to the bottom of the spring, while the spring itself, after the throw, still clings by its other end to the rod. The seed is held lightly in place by a little tuft of hairs that grow over it from the far end of the knob, but exactly at the right time, while the spring is curling up, the hairs give and the seed is shot out. When all the seeds have suffered this fate we find the five curled-up springs, still attached to the central rod, like the spokes of a coverless umbrella turned inside out, with an empty knob at the end of each ; the tuft of hairs remains although the seed has of course gone, and it can then be seen and examined quite easily.

Now, while those species that throw the seed enclosed in the knob have the latter more or less rough, wrinkled and like an insect, the seed itself being smooth, in all those that throw it free the knob is not wrinkled, it bears no sort of resemblance to an insect, and the seeds are not smooth ; on the contrary they are beautifully sculptured, although a lens or a

* *Geranium columbinum*, Linn.

microscope must be used in order to see the pattern, which recalls a honeycomb.

This is really a most interesting point of difference ; an insect-like knob would be of no dispersal value to a plant that throws the seed free of it, and a sculptured coat would, so far as one knows, be superfluous to a seed that is ejected while still enclosed in the knob : but whatever the exact use of either may be it is delightful to find that neither of them is possessed by those species to which apparently it would be of no service, while on the other hand one can readily understand the possibility of their very considerable value to their actual possessors.

I have already suggested a way in which a sculptured seed-coat may be of use, and a wrinkled knob, apart from the resemblance to an insect, may likewise subserve burial and anchorage, while the retention of moisture in its depressions would be favourable for germination at the close of the dispersal period.

With regard to the interval that elapses between sowing the seeds and the appearance above ground of the cotyledons, and confining myself to the few species to which I have given most attention, I find that, broadly speaking, the small-flowered ones, the Dovesfoot, the Shining and the Round-leaved Cranesbills, agree with the Herb Robert in requiring a minimum of about three weeks or less, but the large-flowered Meadow Cranesbill took thirty-nine days, not far short of twice as long. In my trials, too, I noticed that its seedlings were eaten much more frequently than those of any of the other four. I did not succeed in catching the culprit in the act, but I have no doubt that it was my inveterate enemy the Garden Snail : he takes his daily meal at night, which perhaps sounds a little

PLATE V.

I. II. III

FIG. 52.—Cut-leaved Cranesbill.

I. Two fruits on the right about to throw their seeds. × 1½.
II. Fruit after the seeds have been thrown. × 1½.
III. A single seed. × 6.

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Irish, and he is usually to be found in the morning not far from the mangled remains of his victims. I have not yet raised all our species from seed, but I know the seedlings of most of them, and in all these the cotyledons are kidney shaped and so much alike that it would be difficult, though perhaps not always impossible, to determine the species before the appearance of any of the foliage leaves: the differences, however, are too minute and technical to be discussed in these pages, and I purposely leave my readers plenty of opportunity for improving and adding to their contents.

CHAPTER X

THE RELATIVES OF THE HERB ROBERT: THE STORKSBILL

I MUST now say a little about the Erodiums, their popular name, Heronsbill, harmonizing with the scientific, which is derived from the Greek word for a heron ἐρωδιός.

The only species that I have had under observation is known also as the Storksbill;* it is a more or less hairy and glandular plant that grows in waste places and on dry sunny banks and heaths, and it is common in Great Britain, more especially by the sea. Despite general appearances there is never any excuse for mistaking it, in any of its stages, for a Cranesbill; the cotyledons are quite different, having one large terminal lobe and two small basal ones like little squares, one on each side of the midrib, and the foliage leaves are cut featherwise.

Instead of one or two flowers to each stalk there are about half a dozen, approximately half an inch in diameter, with rosy petals, and all three Erodiums agree with the Small Dovesfoot in five of the ten stamens being reduced to antherless scales.

There is again no vegetative propagation. The Storksbill is an annual or a biennial in the same sense

* *Erodium cicutarium*, L'Hérit.

as the Herb Robert, but its whole life, from the birth of the seedling until death, is sometimes considerably less than twelve months, for under favourable conditions the early spring seedlings grow up rapidly enough for the fruit to ripen before the winter,

Whenever it is sufficiently warm it appears to live, so to speak, in a hurry, and not, as we shall see, a very methodical one either.

Contrasted with the Meadow Cranesbill, whose flowers, like the laws of the Medes and Persians, alter not either in the form of the corolla or in the orderly sequence of its pollination arrangements, the Storksbill betrays a remarkably instability in both respects. All our wild Geraniums are steady and uniform in the possession of five petals, all of the same size and shape, according to the species, but the same cannot be said of the Storksbill, and the want of stability in its pollination arrangements is more pronounced than in any single Cranesbill, so far as the relative maturity of the anthers and stigmas is concerned.

FIG. 53.—Seedling of the Storksbill. Reduced $\frac{1}{3}$.
C otyledons.

Again, in the Cranesbills there is very little variation in the colour of the flowers of any given species: we can detect slight differences in those of the shingle variety of the Herb Robert, and there is a very pretty dwarf variety of the Bloody Cranesbill,* with light pink instead of crimson petals, but the Meadow Cranesbill is true to its beautiful bluish-purple. White blossoms occur in the Herb Robert and other species,

* *Geranium sanguineum*, Linn.; var. *lancastriense*, Mill.

but, as already indicated, white petals are not of themselves sufficient to justify separation as a variety but only as a form.

Confining our attention for a moment longer to the Meadow Cranesbill, there are ten stamens in two rows of five apiece, and the pollination arrangements are as follows :—

1. The inner stamens mature and shed their grains.

2. The outer follow their example.

3. After the exhaustion of all the stamens, but not before, the stigmas part company and become receptive.

4. The petals fall and the stigmas dry up at the same time.

This orderly sequence seems to be unvarying and to exclude, therefore, the possibility of spontaneous self-pollination.

In the Storksbill things are very different. Its flower agrees with the Geraniums in possessing five petals, but the five antherless stamens do not of course count in pollination.

I will deal with the corolla first, and then with the relative maturity of the anthers and stigmas.

There is a good deal of variety in both the form and the duration of the petals : sometimes they are but little longer than the sepals, and sometimes all of them are twice as long.

Again, two of them may be very small, and the other three much larger and longer, and either with or without a reddish spot. Occasionally one comes upon plants with white blossoms.

The flowers open in the early morning and the petals fall by midday, or during the afternoon, or, at latest, the next day, recalling the Herb Robert.

All these differences in the petals, including their longer or shorter duration, seem to depend to some extent upon whether the plants grow in the sun or the shade.

The flowers with the three long petals are, I think, to be found as a rule in the more sunny and open places, and those in which they are all of the same size in the shadier ; and I will therefore use the word sun or shade, as the case may be, to distinguish the two forms, but without implying exclusive restriction to either kind of place.

It is the former that are capable of retaining their petals through the night and into the next day : the shade flowers, on the other hand, seem always to lose them before or during the afternoon, agreeing in this respect with those of the Shining Cranesbill, although the habit is not so strikingly noticeable in that species.

The probable explanation is that the shade flowers are considerably less adapted to a cross, and resort more quickly than the others to self-pollination.

This suggestion is supported by the relative maturity of the sexual organs in each form of flower.

Generally I could detect no separation in time in the blossoms of the shade plants, but whenever it was possible to make sure of any difference in such a short-lived flower it was the stigmas that matured first, whereas in the sun blossoms separation is the rule, but it is then the anthers that shed their grains before the stigmas become receptive.

Thus the plants in the sun make the higher bid for cross-pollination both in the marked separation of the sexes and the longer life of the petals.

I do not know whether the earlier maturity of the anthers gives them any additional advantage in the same direction. As one might expect from the smallness of the flowers their insect visitors are not very numerous, but self-pollination takes place readily in their absence.

Thus between these two species, the Meadow Cranesbill and the Storksbill, the contrast is great alike in the form or forms and in the natural history of the flowers. The other Cranesbills present us with many gradations between these two extremes, so far as the pollination arrangements are concerned, but the perennial species are sometimes hard to come by, and the smallness of the blossoms of the annuals rather discounts their attractions for the hobby-botanist; the student, however, should consult the Tables at the end on pp. 162–163 for information. I must add that the period that elapses between pollination and the ripening of the Storksbill's fruit is again three weeks, but we must now leave the flowers and pass on to the history of the seeds.

The fruit might very well be mistaken for a Geranium's, for we have the long bill, the five knobs enclosed in the calyx, and the same mechanism for the first-instance dispersal.

But there is one great difference between the Erodiums and, with one exception, all our own Cranesbills, for the Storksbill and the other two species throw the seed enclosed in the knob which remains attached to the hygroscopic spring.

This is something quite new to us, for in the Geraniums the seed is either thrown free alike of knob and spring, or, if enclosed in the knob the latter does not remain attached to its spring, the one exception being the Dusky Cranesbill which agrees in this respect with the Erodiums, but the dry spring is in a loose coil instead of the close spiral shown in the illustration, Fig. 29.

The Storksbill does not seem to be so successful in throwing its seeds as the Cranesbills are; this is probably due to the extraordinarily hygroscopic spring. We noticed when dealing with the Meadow Cranesbill that a week of rain delayed matters for eight days, but rainy weather seems to be a greater difficulty for the Storksbill. I have often seen the loosened springs in damp showery weather clinging in a tangle around the central rod, whereas when it is fine and dry, they are shot off without any difficulty. Again, the Meadow Cranesbill throws the seed alone, and often to a considerable distance, but the Storksbill's long spring is much more likely to be stopped in its flight by the surrounding herbage. It can be found in fruit from June until the autumn, and it is the late fruits whose seeds fare the worst as regards the throw, though in the end I dare say they are dispersed quite as far as or farther than the others, thanks to the gales blowing them about with the vegetable débris to which they cling.

I have already drawn attention in Chapter VI. to the way in which the seeds are sown and anchored, and I may mention that the same holds good for the Dusky Cranesbill, although the mechanism does not appear to be so perfect. I have not experimented with the seeds of this woodland species, nor have I indulged in much observation of its doings, but I have frequently seen the seeds of the Storksbill firmly anchored in the ground, sometimes only a few inches from the parent; there is no great difficulty about finding them if one looks for the long spring, which sticks out of the soil almost upright, at any rate for a few days, and then rots off.

On the only occasion that I sowed some of them twenty-eight days elapsed before the cotyledons appeared. I regret to add that the seedlings themselves disappeared very soon; they were eaten down to the ground, but here again I did not succeed in catching the culprit in the act. I have no doubt, however, that it was once more the Garden Snail, who usually leaves slime tracks behind him by way of evidence; but be that as it may, not a single seedling of the large number that I once had growing in the garden survived until the autumn. The first one appeared early in July, by the end of September all of them had been devoured, and thanks to the molluscs I am not likely to be worried with the Storksbill as a garden weed. My chief horticultural foe is vastly more abundant in my borders than in the places where the Storksbill grows wild, but on the other hand other kinds of snail may resort to it for a meal; so far, however, I have not made the necessary observations and experiments with this plant. I may mention in this connection that I have never seen it victimised by fungal disease; it is known, however, that it provides some sustenance to the larval world, but like the rest of its relatives it seems to come off rather cheaply in this respect

CHAPTER XI

SUMMARY OF CHAPTERS IX AND X

THE point that I wish to bring out from these comparative observations is one that holds good for many, but not by any means for all other genera and their near relatives, and it is this: that although we find very great uniformity in the life-history in general of the Herb Robert and its relatives, there are equally striking differences. I will mention five of the most interesting: (1) The instability of the floral arrangements of the Storksbill compared with those of the Meadow Cranesbill: (2) the five antherless stamens of the Erodiums and the Small Dovesfoot, and the preponderating self-pollination of the latter and of the shade flowers of the Storksbill; (3) the sculptured seeds of the Cut-leaved Cranesbill, for example, compared with the insect-like knobs of the Herb Robert among others, especially in view of the difference in the first-instance dispersal; (4) that the typical Herb Robert as opposed to its shingle variety is the only one of all our wild Geraniums that produces "seeds" with long threads; and (5) that none of them except the Dusky Cranesbill has learnt the Storksbill's art of sowing and anchoring its seeds. But these remarks and observations apply only to our own wildlings, and there are something like a hundred and fifty species which are not British, which are never found in the United Kingdom even apparently wild, and about which I know nothing whatever that is worth recording.

I must now hark back for a few minutes to the seven factors of life.

In this chapter and its predecessor I have ignored not only respiration and nutrition, but also growth, because there was nothing of special interest to add to what I had said already in Chapter VII.

With regard to Protection, what is true of the Herb Robert is also, broadly speaking, true of its near relatives, although they do not appear as a rule to be quite so free from fungal and other foes. The glandular hairs seem to be of some pretty weighty importance in this respect, not only upon the leaves and stems, but also upon the sepals and the bill, protecting the pollen grains and ovules from the unwelcome visits of crawling insects, and the bill of some of the other species from being attacked by green fly, and spoilt for its important work of throwing the seeds.

Passing on to the fifth factor, the minimum resting period of the seed in my own limited observations shows no startling disparity, for the thirty-nine days of the Meadow Cranesbill compared with the eleven of the shingle variety of the Herb Robert cannot be allowed to count for much: the difference amounts only to four weeks, and I am acquainted with genera of other families containing some species whose seeds germinate in a few days and others that lie over until the next spring. Moreover, the difference in time in seeds taken from the same plant or even from the same fruit, is often a great deal more than a month, the Herb Robert itself being a case in point. The real interest is not in the disparity but in the uniformity, both in the shortness of the minimum resting period and in the power, under suitable conditions, of germinating promptly; moreover, my observations on this point extend as yet only to six of our twelve species of Geranium and one of our three Erodiums.

I may commend to the reader's notice the leafy winter rosettes of our annual Cranesbills and of the Storksbill; they are beautiful in themselves and in the arrangement of their foliage. The large-flowered species of Geranium that I have grown generally die down to the ground-level in the autumn after the usual manner of herbaceous perennials, save for a few radical leaves.

The reproductive arrangements agree in the absence of spontaneous vegetative propagation, and there is not a great deal of difference in the pollination plans; it is rather a case of the same tune with some decidedly pretty variations.

As regards the separation of the sexes in time, instability characterizes the Storksbill especially, and our annual, as opposed to our perennial Cranesbills, are not altogether innocent of the charge. Sometimes the anthers have the first innings, but it is more usually the stigmas: simultaneous maturity is by no means uncommon, and there is always a decided overlap.

The perennials, on the other hand, are considerably more steady, and in all of them the rule is for the anthers to mature before the stigmas. I know no instance of the order being reversed, but in the Wood Cranesbill on rare occasions they both mature at the same time.

Cross-pollination is the rule, and it is not impossible in any one of them, whether annual or perennial, and in all of them except the Meadow, the Dusky and perhaps the Mountain Cranesbill provision is made for self-pollination too. In my own experience it does not often take place in the Bloody Cranesbill or its varieties, but it occurs in the Wood Cranesbill, not regularly, but on those rare occasions when the stamens and the stigmas mature at the same time.

With the annuals self-pollination is on the other hand quite common in every one of our species, while in the Small Dovesfoot and the Storksbill in the shadier places it seems to be the rule almost but not quite to the exclusion of a cross.

The greatest difference that I noted in the time that elapses between pollination and seed maturity amounted to seventeen days, twenty-eight for the Meadow Cranesbill as against eleven for the shingle variety of the Herb Robert, which also took the first prize for quick germination. In all the other species that I watched, including the Storksbill, it was twenty-one; but this is not a matter that need detain us, the interest again lying in the uniformity, and my observations being confined within the same limits as those upon the minimum resting period of the seed.

As for the last factor, the Care of the Children, we have found that the mechanism of the first-instance dispersal is exactly the same throughout, for in Cranesbills and Storksbill alike the style breaks up into five elastic strips, which are capable of throwing the seeds to a considerable distance.

It is when we come to the details of the arrangements that we find sharply marked differences as set forth in Table II., page 163, nor must we forget the skill of the Storksbill, possessed also, but in a lesser degree by the Dusky Cranesbill, in anchoring its seeds in the soil often within a very short time of their ripening.

All the five points to which I drew attention just now refer to the sixth and seventh factors of life, the first two to Pollination and the other three to the seeds, the chief interest being found in the arrangements for the first-instance dispersal; and so I may fittingly bring this summary to a close by asking the reader to give attention to the tables that appear at the end of this book, and the Nature-student to confirm or add to them by making observations of his own. I cannot vouch from my own personal knowledge for every detail of Table I., because for the sake of completeness I have included therein, as well as in the text, reliable observations already recorded by competent observers, pending an opportunity, not yet in sight, of confirming them myself.

CHAPTER XII

CONCLUSION

THE reader will remember that in previous chapters I have referred more than once or twice to the co-operative principle upon which the Scheme of Creation is founded: I am not about to inflict that subject upon him again except to point out the indispensable necessity for co-operation on the part of Nature-students too.

I remarked in Chapter IX. that anything like a comprehensive comparative study of the life-history of our wild Cranesbills and Erodiums would be a very large order indeed, and that the fourth and the last two factors of life, Protection, Reproduction and the Care of the Children afford an absolutely limitless scope, including what is easy, difficult, very difficult and altogether impossible within the capabilities and lifetime of one human being.

I think I may claim to have justified, in the intervening pages, both these assertions and thus to have supported, were any support needed, the plea for co-operation.

When, in the first chapter, I laid down three golden rules, I said that I should have to refer again in this one to the first of them.

It was right in that place to emphasize the importance of seeing and doing things for oneself and to insist upon the rule being respected scrupulously; but now that we have put theory to the test of practice and gained, I trust, some little experience, it is equally right that I should explain that I did not mean that one was to ignore the work of one's fellow-labourers, or that one was to waste time in proving once more what had been proved already, and never to take anybody else's word for anything at all; but I did mean that one must not remain satisfied with isolated evidence and individual assertion, even and more especially when one produces the evidence and makes the assertion oneself. Proof must always rest upon the authority not of any solitary observer but of at least several competent observers, and, where there is agreement from various quarters, seeing things for oneself in one's own locality may quite legitimately play a secondary, but still an important part.

It may be relegated to the secondary because facts cannot be altered and because well-established conclusions founded upon them are not likely to be disproved, but it remains always important because new facts, as they come to light, must be taken into account, and because they do and will continue to come to light and modify previous induction.

The Nature-student therefore must at all times have his wits on the alert and his eyes wide open, lest in confirming for his own satisfaction some already recorded observation, he miss a point that has hitherto escaped notice or was not presented to previous observers.

He should set himself to acquire the information accessible to all who will, in the spirit of inquiry, read, mark, learn and inwardly digest the work of their predecessors, and then by the addition of his own, his acquired information will rise to the higher level of personal knowledge, whether the induction be modified or not.

It is in this way and in this way alone that a correct mental picture of the subject in hand can be acquired, clear and with the details in true perspective, that progress in Science is achieved and its accuracy enhanced. The more one knows about the natural history of plants the more surely does one realize that they are not hidebound by hard and fast rules of conduct. As we have seen, neither the Herb Roberts on the shingle nor the Storksbills in the shade behave in all particulars like their fellows in the moist hedgerow and on the dry sunny heath respectively, while the hairiness of the Shining Cranesbills which came under my own observation seems to be an unusual feature; plants, like animals and human beings, react in response to a change of circumstances, and it is apparently in that way, although not in that way alone, that new forms appear and new species become established.

When, therefore, the student finds that his observations do not agree with those of other people, he need not conclude that there has been a mistake in his or in anybody else's work, even in the face of a flat contradiction. The better part is to make quite sure of his own results and to confirm them by repetition, for it is just as likely, and if both observers be careful a great deal more likely, that neither of them has erred, but that the different results are due to the different surroundings of the individual plants observed.

I advocate neither cocksureness nor diffidence, but a reasonable faith in one's own work coupled with the respect that is due to one's predecessors and contemporaries in the great and honourable fraternity of working naturalists.

In the first chapter I quoted the motto of the Linnean Society, "Naturæ discere mores," and throughout these pages I have endeavoured to point out one way in which to respond to the call. The motto of our premier learned Society, the Royal, consists again of only three words, "Nullius in verba," and the reader will no doubt understand and appreciate the significance of the genitive singular. If he will also recall what I wrote, when dealing in Chapter III. with mutual competition, anent the definition of the word "Nature," he will grasp my meaning when I say that he should bear both mottoes steadily in mind and keep the fear of them always before his eyes, for upon the correct interpretation of these two hang all religion, every step upward in the advancement of learning, and the whole duty of the Nature-student.

GERAIN

POLLINATION, FIRST-INSTANCE

CRANESBILLS (*British species*) AND

TABLE I.—THE FLOWERS.

Separation of the Sexes in Time.			Pollination Modes.
	Maturity of Sexual Organs.	Overlap.	
Perennial species—			
Geranium phæum	All the anthers first	No	Cross only
,, pratense	Ditto	No	Cross only
,, sylvaticum	Ditto or rarely anthers and stigmas together	Yes, but rarely	Cross and rarely self
,, pyrenaicum	All the anthers first	Very rare, if ever	Cross, and very rarely if ever, self
,, sanguineum	Ditto	Yes	Cross and sometimes self
Annual species—			
Geranium rotundifolium	(1) 5 anthers; (2) stigmas; (3) other 5 anthers	Yes	Cross and self
,, Robertianum	Ditto or rarely anthers and stigmas together	Yes	Cross and, late in the year, self
,, molle	(1) some, but less than 5, anthers; (2) stigmas; (3) the remainder of the anthers Or rarely anthers and stigmas all together	Yes	Cross and self
,, columbinum	Stigmas first, or rarely some anthers before the stigmas	Yes	Cross and self
,, dissectum	Stigmas first, or rarely anthers and stigmas together	Yes	Cross and self
,, lucidum	Stigmas first	Yes	Cross and self
,, pusillum	Ditto	Yes	Cross, but generally self
Erodium cicutarium—			
Sun-form	All the anthers first, or anthers and stigmas together	Yes	Cross and self
Shade form	Stigmas first, or anthers and stigmas together	Yes	Cross and self

ACEÆ.

DISPERSAL, AND ANCHORAGE

STORKSBILL (*Erodium cicutarium*).

TABLE II.—THE SEEDS.

	First-instance dispersal.	Seed-coat.	Peculiarities.
1. Geranium sanguineum	Seed thrown free of knob and spring	All sculptured (6 species)	
2. ,, sylvaticum			
3. ,, pratense			
4. ,, rotundifolium			
5. ,, columbinum			
6. ,, dissectum			
7. ,, pyrenaicum	Seed thrown enclosed in knob but free of spring	All smooth (7 species)	
8. ,, Robertianum			8. "Seed" with two long hygroscopic threads; the shingle variety without any threads.
9. ,, molle			
10. ,, lucidum			
11. ,, pusillum			
12. ,, phæum	Seed thrown enclosed in knob which remains attached to the spring		12 & 13. Bury and anchor the "seed" in the soil by the action of the hygroscopic spring
13. Erodium. cicutarium			

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THE END

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